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Red Ring Disease of *Cocos nucifera* L. caused by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960

An annotated bibliography and review

C. G. Dean

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Red Ring Disease of *Cocos nucifera* L. caused by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960.
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by

C. G. Dean

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List of Contents

1. Preface 1

2. List of Figures 2

3. Red Ring Disease of *Cocos nucifera* L. Caused by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 3

4. Notes on Annotations 22

5. Annotations 23

6. Co-author Index 64

7. Subject Index 65

Preface

Red Ring Disease is a major problem of coconut growing in the Neotropics and one on which much time, effort and money have been expended, particularly by countries that can ill afford such expenditure. There is a vital need for the establishment of a concerted multi-national approach, sponsored and coordinated by an international agency to control this disease which is limiting the production of vegetable oil in the Neotropics. This review and annotated bibliography are intended to provide the basic background information upon which such a study programme could be developed.

I should like to express my gratitude to the coconut growers of El Salvador for permitting me to study this disease in their country, to the Government of El Salvador and the Ministry of Overseas Development, London, for financial support, to Peter Gooch and the staff of the Commonwealth Institute of Helminthology who assisted me with the literature, and last but not least to my wife Lynn, who typed the several drafts of this work. The opinions expressed and the errors contained herein are entirely my own.

C. G. Dean
Nottingham 1979

List of Figures

1. Crop losses of coconut palms due to R.R.D. 6
2. Geographical distribution of R.R.D. and of the arthropods reported as being involved in its transmission. 7
3. Map of the distribution of the R.R.D. nematode and the palm weevil. 8
4. Illustration of *Rhadinaphelenchus cocophilus*. 10
5. Means and ranges of measurements of *Rhadinaphelenchus cocophilus*. 11
6. Alternative host plants for *Rhadinaphelenchus cocophilus*. 11
7. The proportion of black palm weevil populations carrying R.R.D. nematodes. 14
8. Factors (other than identified insects) associated with the transmission of R.R.D. 15
9. Alternative host plants for the palm weevil, *Rhynchophorus palmarum* L. 15
10. Possible biological control agents for the palm weevil. 17

The cover photograph is of one longitudinal and two transverse sections through a 10 year-old, R.R.D. coconut palm, taken in El Salvador by the author.

Red Ring Disease of *Cocos nucifera* L. Caused by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960*

C. G. DEAN

ORIGIN OF THE COCONUT PALM

The geographical origin of the coconut palm, *Cocos nucifera* L., is uncertain. Considerable circumstantial evidence exists for a Neotropical origin in the northwestern region of South America along the Pacific coasts of Colombia and Ecuador. This is an area which presently contains a majority of the palm species most closely related to the coconut. Credible evidence also exists for possible Indonesian, Melanesian or Polynesian origins. Heyerdahl (1952) supports Cook (1910–12) and others in their opinion of a South American origin and reviews the evidence for the spread of the palm, carried by man, to Polynesia and the evidence against an eastward spread from Indonesia. Much of this evidence, while circumstantial, is convincing when associated with the evidence for the Pre-Colombian existence of the coconut palm on the Pacific coast of south Central America and northern South America. Oviedo (1535–48) describes coconut palms growing on the Pacific coast of the Isthmus of Panama in 1526 which could not have been introduced by European travellers. Pizarro (1921) reports coconuts ('cocoa nuts') as being amongst the cargo of food offered to him by the natives who sailed out to meet him at Tumbez on the northwestern point of Peru in 1527 (1529?) and Cieza de Leon (1553) refers to the presence in 1532 of these palms in Colombia and the practice of using their oil as fuel for lamps. This report may, however, refer to the Cohune palm (*Attalea cohune*). Coconuts are also listed amongst the fruits represented in ancient Peruvian effigy jars.

Considerable evidence exists for Pre-Colombian sea trade along the Pacific coast from Peru through Mesoamerica as far north as Mexico. Wafer (1903) reports the presence of established coconut plantations on the Cocos Islands, off the coast of Costa Rica, in 1685. The movement of agriculturally important seeds through this area by man is indicated by the presence in Peru, at least 1000 years BC, of the cultivated Mesoamerican variety of *Zea mays*. In addition, the interchange of trade items is evidenced by the recoveries from Mesoamerican archaeological sites of Pre-Colombian South American ceramics and also golden artefacts of similar date, from Colombia.

The coconut palm was not, however, established in the Caribbean area or Atlantic coast of South America before the arrival of the Spaniards. Bruman (1944) reports that the coconut was brought to Puerto Rico in 1549 from the Cape Verde Islands after having been brought to West Africa by Portuguese traders returning from Asia after A.D. 1500. These same traders later introduced the coconut into Brazil. Coconuts were introduced into Surinam in 1685 by the Governor, van Aerasen van Sommelsdijk. Sloane (1696) reports that by 1696 coconuts were widespread throughout the Caribbean. There is evidence to suggest the introduction into Mexico from the Philippine Islands of coconuts and techniques for their cultivation and use, following the establishment of the Spanish missionary route from Acapulco to those islands.

Although it is not possible to establish conclusively that Mesoamerica or South America is the original home of the coconut, there is considerable evidence to suggest that the Panama Tall variety (PT) (previously called the San Blas variety) had a Pre-Colombian existence on the Pacific coast, probably extending from the northern tip of Peru along the Mesoamerican coast to Mexico. In contrast, the Jamaica Tall variety (JT) now established throughout the Caribbean and on the Atlantic coast from Florida to Brazil, arrived post-conquest via Africa from Asia. A difference may therefore be expected between the PT and JT varieties in their tolerance to such indigenous pathogens as R.R.D. and lethal yellowing disease.

* Only those authorities not included in the annotations are included in the references attached to this review; they are referred to by author and date. Others are referred to by the annotation number only. Authorities for much of the information given in the text may be located through the index to the annotations.

THE ESTABLISHMENT OF THE COCONUT INDUSTRY

Until the end of the nineteenth century coconuts were not grown as a major plantation crop in the Neotropics, although, by that time, they occurred in abundance on the Caribbean islands and along parts of the coasts of Central and South America away from the mangrove swamps. They were cultivated and used extensively by the coastal inhabitants, but never to the extent to which they were utilized in Asia and Oceania.

The establishment of coconuts as an export crop from the Neotropics followed the development of a soap manufacturing industry in Europe about 1841 and the discovery in the 1870s of a process for the hydrogenation of coconut oil to produce margarine. Until that time, the only coconuts exported were those used as packing between barrels of pitch from Trinidad. They were sold on arrival in London for the manufacture of oil and to supply the upholstery industry with a relatively non-flammable fibre for stuffing. The supply of coconuts for these export requirements could be met from the naturally reseeded coconut groves growing on good land suitable for such cultivation along the coastal strips. In 1863 only 226,791 nuts were exported from Trinidad, but by 1881 this figure had risen to exceed 6 million (Pieris, 1941). With this increased demand from Europe and with the depression in the sugar industry at the turn of the century, coconuts began to be planted as formal plantations on old sugar-cane land, which was often not suitable for such use. Following the further decline in sugar and cacao prices, after the 1914–18 war, more of this unsuitable land throughout the Caribbean area was converted to coconut growing. In Trinidad the area under coconuts increased rapidly from 5665 ha. in 1902 to 8093 ha. in 1910, 12,140 ha. in 1921 and to 18,211 ha. by 1930. Industrial demands for oil decreased from this time as a result of an increasing dependence upon mineral oils. However, with the current significant increase in the price of mineral oils and the political limitations related to their supply during the 1970s, coconut and other vegetable oils have again assumed a role of major importance in the world market.

THE HISTORY OF RED RING DISEASE (R.R.D.)

The establishment of formal plantations in the southern Caribbean area with palms all of the same age, often on unsuitable land, accounts for the sudden recognition of the major significance of R.R.D. and other problems affecting coconuts in the Neotropics. Previously where groves were naturally seeded and palms varied in age, the deaths of individual plants did not arouse the same concern which, at the turn of the century, was created by the deaths of large numbers of palms in plantations. That these plantations were established on old sugar-cane land and that some of the insect pests of sugar could also attack or live in coconut palms led to the suggestion in the early literature of the dangers of planting coconuts on old sugar-cane land. It was the unsuitability of the land for coconuts rather than some inherent disease in the soil that was one of the major causes of crop losses. It was, however, recognized that poor cultivation alone could not account for the ever increasing loss of palms.

In 1905 Hart, the Superintendent of the Royal Botanic Gardens, was invited to Trinidad to examine a serious disease which was affecting coconuts on the southwestern coast of the island at the point closest to the coast of Venezuela. He reported that the disease had 'been present in more or less severity for several years'. He isolated bacteria and fungi from the leaves and the stem, observed rotting of the tissue of the crown and recorded that one of the symptoms was a red ring, seen in cross-sections of the stems of the diseased palms, extending up the inside of the stem and into the leaf bases. He found no correlation between this condition and the presence of palm weevils. In 1905, Buck of the United States Department of Agriculture also visited the Cedros district of Trinidad and reported on a serious disease of coconut palms which he considered to require immediate attention (no report available at U.S.D.A.).

Barrett visited Trinidad in 1907 and found up to 50% of the palms affected by a 'root disease' (R.R.D.) but very few affected by bud rot or palm weevils. He distinguished between root disease (R.R.D.), bud rot and rotting of the bud following damage to it. He reported that in root disease the location of the red ring was either central or peripheral, that a palm died within four months of first developing symptoms and that death of surrounding palms was delayed for up to twelve months. The control measures that he recommended included destruction of infested material, isolation of the diseased area, chemical spraying of the land, the improvement of cultivation and a search for resistant varieties. These recommendations are, in general, those which are still made today!

Fredholm, visiting the area in 1909, established a clear distinction between the symptoms of bud rot and those of root disease; a distinction with which Johnson disagreed but with which Rorer concurred. Harrison and Stockdale reported the presence of R.R.D. in Guyana, the first identification of root disease on the South American continent. In 1918 Nowell reported its presence in Grenada and noted an association between the disease and a nematode. In 1919, in a major review paper on the condition, he named it 'red-ring disease', in order to distinguish this condition from other root diseases. He also confirmed that a nematode was the causal agent of R.R.D. Nowell sent specimens of the nematode to Cobb at the United States Department of Agriculture and in the same year Cobb published his description of *Aphelenchus cocophilus* Cobb, 1919. Subsequent workers reported the presence of R.R.D. throughout the continental Neotropics and elaborated upon descriptions of symptoms and possible alternative methods of spread and control of the disease.

A major study programme was undertaken based on Fenwick's report in 1957 to the Ministry of Overseas Development in London. This project was undertaken by the Trinidad and Tobago Coconut Research Limited over a period of twelve years. In addition, a research programme was also undertaken by the Ministry of Agriculture in Trinidad. These two groups did not always agree. The difference of opinion centred around the relative importance of soil transmission of the disease in contrast to spread of the nematode directly from palm to palm by the palm weevil. Much information was gathered by these two groups with respect to symptomatology and control methods relevant to R.R.D. under the specific conditions which exist on the islands of Trinidad and Tobago. It may be dangerous at the present time to depend entirely upon their recommendations when treating R.R.D. under continental, in contrast to island, conditions and in areas growing cultivars or varieties of coconuts other than those encountered in Trinidad and Tobago.

Griffith has recently proposed an elegant hypothesis which relates R.R.D. transmission to the size structure of the palm weevil population and implicates only the smaller specimens in the population as being responsible for the spread of the R.R.D. nematode. Such a size relationship was not found by other workers either in Grenada or in El Salvador.

THE ORIGIN OF R.R.D.

R.R.D. was recognized as a major problem of the coconut industry only after the recently increased establishment of plantation growing of the palm. Coconuts are not native to the Caribbean or to the eastern seaboard of the Americas. The South American jungles are, however, the home of those palms most closely related to the coconut and may indeed be the home of the coconut palm itself. R.R.D. must therefore have developed in the jungles of South or Central America associated with various palm species. The present list of the alternative hosts of the R.R.D. nematode (see Figure 6 later) is limited to thirteen species. This small number reflects the limitation of study rather than the real number of hosts. The association of the nematode with various insects, especially coleopterans, reflects only the general association of the Aphelenchida with such insects rather than a unique association.

CROP LOSSES

From the time of its first discovery, R.R.D. was recognized as a major cause of crop loss in coconut plantations. Assessments (Figure 1) of the extent of these losses vary greatly and it is often unrealistic to assign a percentage loss to a disease which can completely eliminate a young plantation. In addition, since young palms of many varieties of coconut are the most susceptible, surveys in areas where the age structures of palm populations differ, cannot give consistent results. Further difficulties in attributing a true crop loss value are caused by the intimate association of the R.R.D. nematode with the black palm weevil *Rhynchophorus palmarum* L. and other insects which are themselves pests of the coconut palm. It is often a moot point as to whether a palm has died as a result of the nematode burden or the palm weevil infestation.

GEOGRAPHICAL DISTRIBUTION OF R.R.D.

At the present time, R.R.D. is known to occur throughout the mainland Neotropics (Figure 2 and 3) but extends northwards up the Lesser Antilles only as far as St. Vincent (Figure 2 also

FIGURE 1 CROP LOSSES OF COCONUT PALMS DUE TO R.R.D.

% Crop loss	Country	Annotation No.
0–74	Grenada	270
0–98	El Salvador	—
1–48	Trinidad	10
4·7–60·6	Trinidad	160
7	Guyana	165, 267, 268
22	Grenada	269, 270
30	Belize	58
30	Grenada	243, 244
30	Colombia (Mosuera)	260
35	Trinidad	65
40	Venezuela	264
50	Colombia (San Juan)	260
60	Trinidad	229
61–78	Trinidad	92
80	Tobago	62, 65
80	Colombia (Iscuande)	260

indicates the general geographical distribution of the insects which have been associated with the spread of this disease). The present northern limit, St. Vincent, must be considered to be a temporary one. With its chief transmitter *Rhynchophorus palmarum* ranging at least as far north as Guadalupe, and the St. Vincent passage being only some 32 miles wide, the limited quarantine regulations may not be able to prevent its entry first into St Lucia and then northwards up the Antillean chain. Prevailing winds and currents, being generally westerly, mitigate against sea-borne transmission of diseases northwards through the Lesser Antilles and indeed have also probably helped in preventing the eastward spread of the lethal yellowing disease of coconuts to the Lesser Antilles from the Greater Antilles.

On mainland America, R.R.D. extends southwards from the central coastal regions of Mexico, (Veracruz on the Caribbean and Colima on the Pacific) and through all the countries of Central America. In South America, on the Pacific coast, the disease extends south at least to Tumbes in northern Peru, while on the Atlantic coast it has been reported in the State of São Paulo in Brazil. Absence of reports of the disease from Guatemala and Nicaragua reflect only a lack of study in those areas. In the Yucatan, Mexico, there are unconfirmed sightings of the disease which are probably valid. R.R.D. does occur along the Caribbean coast of Guatemala from Livingston to the Belize border and on a number of the small offshore islands. In Nicaragua, the disease occurs on the Caribbean coast in the Bluefields/El Bluff area and inland at Rama on the Rio Escondido. It has not been identified on Great Corn Island east of Bluefields, a small intensive coconut growing area, nor on the Atlantic coasts of Honduras or northern Nicaragua where few coconuts grow. In addition to its occurrence on mainland Panama, the disease is a major problem on the San Blas Islands off the Caribbean coast. The absence of reports of the disease from French Guiana probably also reflects an absence of reported studies since the disease is otherwise endemic throughout that coast. Reports of the disease in: Belgian Congo (Zaire); Cuba; the Fiji Islands; India; Malaya and Oceania are erroneous. Several surveys confirm the absence of the disease outside the Neotropics. It is confirmed that the disease does not occur in Africa, Southeast Asia, Malaya, the Pacific Islands, the northern Caribbean islands, Florida or Cuba.

The reported absence of R.R.D. from Guyana and Surinam was followed by several reports of its presence there, associated with little-leaf disease symptoms, in coconut and oil palms and in the wild palms *Mauritia flexuosa* and *Maximiliana maripa*. On coconuts in these countries the disease is of less significance than has been reported from other areas of the Neotropics. R.R.D. is, however, of considerable importance in these two countries due to its effects on the oil palm (*Elaeis guineensis*). It has been suggested that the distribution of the R.R.D. nematode is significantly influenced in both Guyana and Surinam by the native practice of cultivating palm weevil larvae in split palm stems in the jungle for food. This is said to account for the high incidence of adult weevils recovered in Surinam infested with R.R.D. nematodes in an area where R.R.D. is not a problem in coconut plantations. This indicates the importance of wild palms as reservoirs of both the palm weevil and R.R.D. Cultivation and collection of palm weevil larvae for food was also practised in Trinidad

FIGURE 2 GEOGRAPHICAL DISTRIBUTION OF R.R.D. AND OF THE ARTHROPODS REPORTED AS BEING INVOLVED IN ITS TRANSMISSION.*

Distribution of R.R.D.

Confirmed: Belize (1), Brazil (2), Caribbean Area (3), Central America (4), Colombia (5), Costa Rica (6), Ecuador (7), El Salvador (8), Grenada (9), Guatemala (10), Guyana† (11), Honduras (12), Mexico‡ (13), Neotropics (14), Nicaragua (15), Panama (16), Peru (17), St. Vincent (18), South America (19), Surinam (20), Trinidad & Tobago (21), Venezuela (22).

Unconfirmed: Antigua (a), Argentina (b), Barbados (c), Bolivia (d), Cayman Isles (e), Cuba (f), Dominica (g), Dominican Republic (h), French Guiana (i), Guadeloupe (j), Haiti (k), Jamaica (m), Martinique (n), Montserrat (o), Northern Caribbean Area (p), Paraguay (q), Puerto Rico (r), St. Kitts, Nevis (s), St. Lucia (t), Uruguay (u), Virgin Isles (v).

Distribution of Arthropods involved in R.R.D. Transmission

Ants	?5, 16, ?22
Coptotermes niger	16, 21
Dinamis politus	2
Eutermes sp.	16
Hemiphileurus sp.	21
Hololepta sp.	21
Homalinotus coriaceus	2, 21
Insects	9, 21
Isoptera	21
Leucotermes tenius	16
Metamasius hemipterus	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 22, a, b, c, d, f, g, h, i, j, k, m, n, o, r, s, t, u, v, cosmopolitan
Nasutitermes ephratae	16, 20
Parisoschenus obesulus	2
Rhinostomus barbirostris	1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, b, d, i, q
Rhynchophorus palmarum	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, b, d, g, i, j, n, p, u
Spiders	cosmopolitan
Strategus aloeus	1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 22, d, i, m, p
Strategus spp.	1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 22, d, e, f, h, i, k, m, p, q, r, u, v
Tarantulas	cosmopolitan
Termites	16

*Where the generic or common name only is identified, the country of origin of that report is cited when it is clear that such transmission actually occurs in that country and is not cited as part of a literature review.
†Early reports indicating its absence were later repudiated.
‡See index for distribution within States.

(Wolcott, 1933) and other areas of the Caribbean and probably also in other parts of South America. Larvae of *Strategus aloeus*, also a potential transmitter of R.R.D. are also collected and eaten in Guyana (Ratcliffe, 1976) and in the Caribbean.

NOMENCLATORIAL HISTORY

The R.R.D. nematode was originally described by Cobb in 1919 as *Aphelenchus cocophilus* from coconut palm roots from Grenada, West Indies, which were preserved by plunging them into 70% alcohol. The roots were supplied by Nowell. Based on Cobb's original description, the nematode was transferred to the newly erected subgenus *Chitinoaphelenchus* by Micoletzky. Later, based upon this same description, T. Goodey placed it in *Aphelenchoides* and Filipjev (1934) transferred it to the subgenus *Aphelenchoides* (*Aphelenchoides*) before Fuchs (1937) transferred it to *Aphelenchoides* (*Chitinoaphelenchus*). Chitwood in 1959, based on his study of preserved material of adults and larvae recovered from coconut tissue in Trinidad (probably supplied by Fenwick), placed the nematode in *Chitinoaphelenchus,* overlooking the fact that in 1935 he had made *Aphelenchoides* (*Chitinoaphelenchus*) *ormerodis* Ritzema Bos, 1891 (= *Aphelenchoides parietinus* (Bastian, 1865)) the type species of *Chitinoaphelenchus*. Since the R.R.D. nematode is not closely related to either *A. ormerodis* or *A. parietinus*, J. B. Goodey, in 1960, erected a new genus *Rhadinaphelenchus* and placed *R. cocophilus* in it as the type and only species. J. B. Goodey based

FIGURE 3 MAP OF THE DISTRIBUTION OF THE R.R.D. NEMATODE AND THE PALM WEEVIL

Geographical distribution of R.R.D. ————
Geographical distribution of the palm weevil .....

his description on the previous literature, the work of Lordello and Zamith and on new material fixed in TAF and mounted in glycerine, provided by Fenwick from coconut palms in Trinidad. Lordello and Zamith's description was based on material collected in the state of Rio de Janeiro, Brazil, examined fresh and measured and drawn after fixing in 6% alcohol. The genus *Rhadinaphelenchus* was placed by Paramonov (1962) in the newly erected subfamily Rhadinaphelenchinae. In 1967, Husain and Khan (1967) claimed originality in erecting this subfamily but had been pre-empted by Paramonov's 1962 action.

Rhadinaphelenchus resembles *Bursaphelenchus* Fuchs, 1937, *Parasitaphelenchus* Fuchs, 1929, and *Huntaphelenchoides* Nickle, 1970 in the possession of small terminal caudal alae and it resembles the two latter genera in the shape of the spicules, in which the ventral element terminates at a level with or some distance posterior to and separate from the dorsal element. There is therefore a very close relationship between *Rhadinaphelenchus, Huntaphelenchoides* and *Parasitaphelenchus*. Siddiqi follows Nickle in suggesting that they may belong within the same subfamily.

The full systematic position of the R.R.D. nematode is therefore: Tylenchida, Aphelenchina, Aphelenchoidea, Aphelenchoididae, Rhadinaphelenchinae, *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960.

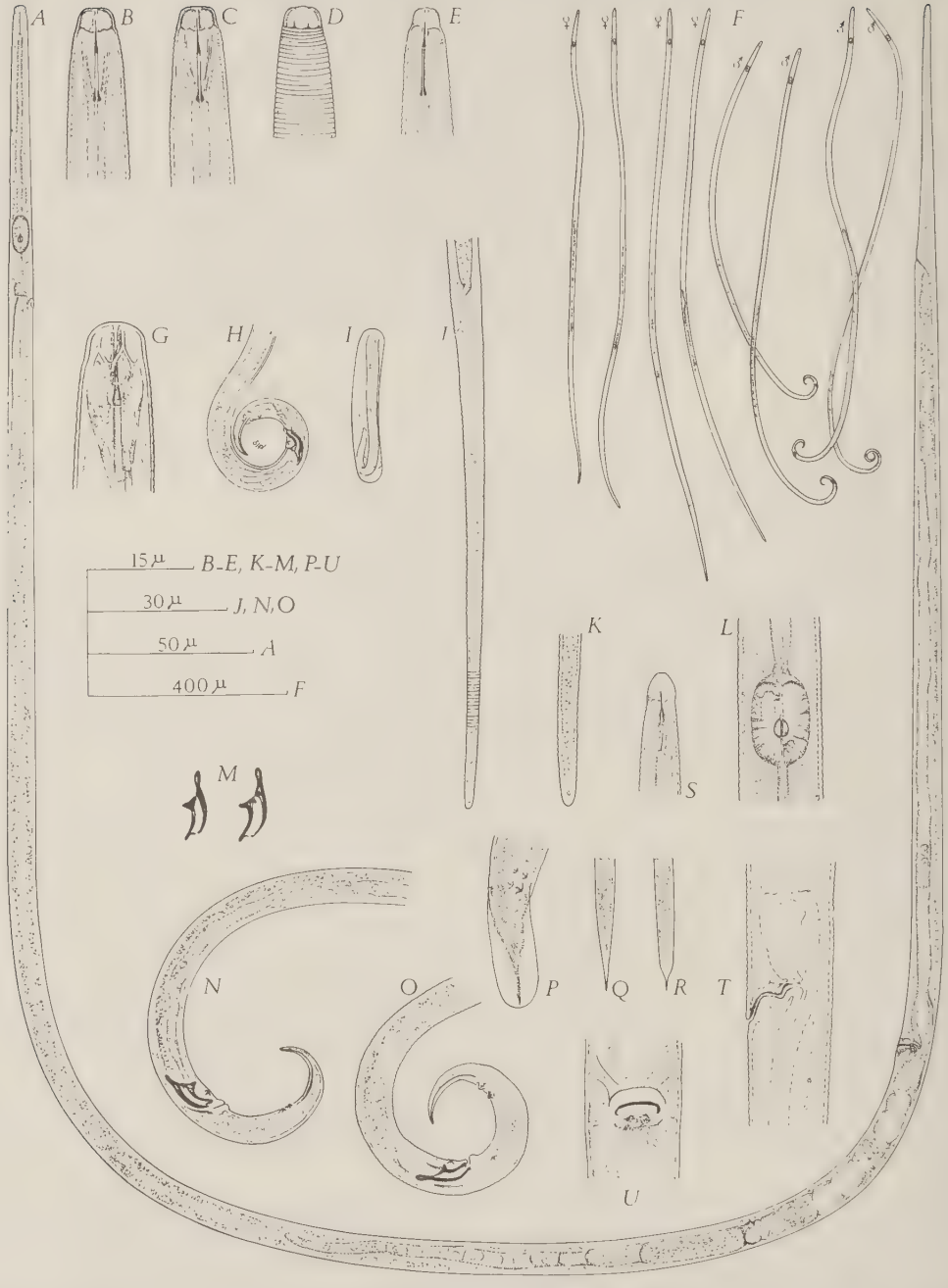
DESCRIPTION

This description which is supplemented from the literature is based on that of Siddiqi who based his description in part on a re-examination of J. B. Goodey's material. For illustrations and details of body measurements and ratios see Figures 4 and 5.

Female: body about 1 mm long and very slender (a = 60–115), arcuate to nearly straight when relaxed; cuticle thin, marked with transverse striae, 0·6–1 μm apart; **lateral fields** with 4 incisures, occupying 0·25 of the body-width, and a faint median line suggesting a fifth incisure; the outer incisures are crenate (143); **deirids and phasmids** absent. **Lip region** smooth, high, anteriorly flattened with rather straight sides, slightly narrower than, and set off from the body; **head framework** prominent, sclerotized, a hexaradiate ribbed cylinder with sides forming fine bars which bifurcate basally, but not so exaggerated as Cobb (38) indicated (143) (Figure 4G). **Spear** 11–13 μm long (15·3 μm (200), 16 μm (160)), attenuated, knobbed at the base and well developed (239, 299), knobs may be obscure especially on immature specimens (291); the anterior part less than half of the spear length and sharply pointed; protractor muscles of the spear prominent, attached to the basal plate of the labial frame-work. **Procorpus** elongate-cylindrical; **metacorpus** or **median bulb** oval, usually about twice as long as wide, with prominent **valve-plates** just posterior to the centre of the bulb; **Dorsal oesophageal gland orifice** midway between the anterior margin of the bulb and the valve plates. **Oesophageal glands** overlapping the intestine dorsally, usually obscure. **Nerve ring** a wide band surrounding the isthmus about 0·5 to 1 bulb-length behind the bulb; excretory pore a little behind the nerve ring and anterior to the hemizonid which is about 3 annules long. **Intestine** with small granules and indistinct lumen. **Vulva** slit-like appearing as an open C in ventral view (Figure 4U), slightly overhung by a wide, thick dorsal lip (vulval flap seen in only 1 out of 12 specimens examined by Esser (in 28), but illustrated as extensive by Thorne (291)); posterior lip is also thick and heavily sclerotized. **Vagina** thick-walled, slightly curved, or distinctively C-shaped (291) as it leads inwards to a distance of about 0·5 of the body-width. Anterior **gonad (ovary)** well developed, outstretched; oocytes in a row. **Postvulval uterine sac** elongate, initial section with thickened walls probably representing part of the uterus (143), extending to about 0·75 of the vulva-anus distance, and serving as a spermatheca (291), often with a few large spheroid sperms. **Rectum** about 1·5 anal body-widths long; **anus** distinct, the opening 0·25 (143) to 0·5 (200) of anal body-width. **Tail** elongate-subcylindrical with a rounded, unstriated terminus, 10–17 anal body-widths long.

Male: Body about 1 mm long and very slender (a = 65–179), ventrally arcuate, more strongly curved in the tail region. **Head, spear** and **oesophagus** as in the female. **Testis** single, anteriorly outstretched to over 0·5 of the body length, with spermatogonia in a row. **Spicules** paired, thorn-shaped, small; dorsal limb 9–13 μm long with an elongated rounded apex and ending distally before the ventral limb whose distal end appears to recurve to join the dorsal limb so that the entire spicule appears notched distally; the ventral element, 7–8 μm long (143, 148, 150), has a distinct rostrum proximally and appears to be connected to the dorsal limb through a transverse bar with a central hole (Figure 3M). No **gubernaculum,** but the dorsal wall of the **spicule pouch** is thickened to form

FIGURE 4 *RHADINAPHELENCHUS COCOPHILUS*



A & F. Adults; B–D & G. Female head ends; E. Male head end; H, N & O. Male tail ends; I. Egg; J. Female tail; K. Female tail tip; L. Female median oesophageal bulb; M. Spicules; P. Bursa in dorsal view; Q & R. Larval tail tips; S. Larval head end; T & V. Vulva in lateral and ventral view, respectively. G, H & I. after Cobb (38); T. original Siddiqi; rest after Siddiqi (28).

FIGURE 5 MEANS AND RANGES OF MEASUREMENTS OF *RHADINAPHELENCHUS COCOPHILUS*

Annotation No.

Female

	L (mm)	a	b	c	V	Spear (μm)
38	1·0	71·4	7·6	12·5	$^{28}68^{13}$	16
119	1·04–1·32	87–115	15–18	9–13	62–78	
143	0·97(1·05)1·18	78(87)96	8·7	9·5(11·6)13·2	$^{25\text{-}41}64(^{36}66^{20})68^{18\text{-}21}$	12–13
148	0·9–1·1	83	20	50*		16
200	0·83–1·11	60(76·4)96	11(12·3)14	9·4(10·2)10·7	66(67·2)69	15·3
291	1·2	69	8·4	12	$^{35}65^{20}$	

Male

	L (mm)	a	b	c	T	Spear (μm)
38	1·0	100	7·6	20	45	16
119	0·8–1·17	71–120	11–15	11–32		
143	0·84(1·02)1·16	100(120)179	6·5	24(28)35	50(59)68	12–13
148	0·82–1·05	100	20	30		16
200	0·83(1·01)1·42	92(107·6)143	11(13·0)19	22(31·6)47	30·6(32·4)36·7	10·7(12·3)13·8
291	1·0	65	7·8	19	42	

*erroneous.

an **apophysis,** referred to as a gubernaculum by Filipjev and Schuurmans Stekhoven (117). **Anus** with anterior lip protruding (143), posterior lip protruding (199, 200) or with both lips protruding (28). **Tail** strongly curved ventrally, 0·8 (143, 200) to 1·5 (28, 150) of a circle, subcylindrical in the anterior half, then conoid to a pointed terminus. **Bursa (caudal alae)** short and terminal, prominent in dorsal or ventral view (not easily detectable in lateral view as it does not project beyond the tail contour) with finely striated margins, enveloping the distal 0·4–0·5 of the tail. There are two pairs of distinct ventro-submedian **papillae** near the base of the bursa and a pre-anal pair, about 0·5 of the spicule length anterior to the anus; a fourth pair of ventro-lateral papillae behind the anus has been reported (239, 299), these are very obscure and often not detectable.

Larvae: with high, dome-shaped **heads,** not offset from the body. The **tails** of the second- and third-stage larvae have conoid or sharply mucronate tips (Figure 4R), and those of fourth-stage larvae have dimorphic tips: in female larvae they are rounded as in the female, and in male larvae sharply drawn out (Figure 4Q).

FIGURE 6 ALTERNATIVE HOST PLANTS FOR *RHADINAPHELENCHUS COCOPHILUS*

Plant	Annotation No.
Acrocomia aculeata	28
Acrocomia intumescens	146
Attalea sp.	221
Cabbage palm	5, 291
Elaeis guineensis	28, 37, 46, 62, 115, 117, 119, 146, 149, 150, 202, 203, 204, 205, 207, 221, 249, 250, 256, 257, 258, 259, 260, 272, 280, 281, 311, 314, 315
Elaeis sp.	115, 196
Gru-gru palm	5, 291
Mauritia flexuosa	28, 203, 204, 280
Maximiliana maripa	28, 203, 204, 280
Phoenix canariensis	62
Phoenix dactylifera	37, 46, 62, 115, 117, 119, 146, 149, 150, 207
Phoenix sp.	196
Roystonea oleracea (= *Oreodoxa oleracea*)	25
Roystonea regia (= *Oreodoxa regia*)	62, 119, 146, 287
Roystonea sp.	196
Weeds	29

ALTERNATIVE HOSTS OF *RHADINAPHELENCHUS COCOPHILUS*

In addition to the coconut palm (*Cocos nucifera* L.), a number of other palms (Figure 6) have been recorded as alternative hosts of the R.R.D. nematode. In addition to these palms, it has also been suggested that various weeds in the ground flora of coconut plantations could act as alternative hosts. No such non-palm species has yet been confirmed as a host nor have these nematodes been recovered from any tissue of any plant other than a palm.

Of the palms listed as alternative hosts, the three *Phoenix* species and *Elaeis guineensis* are of old world origin while the remainder originated in the Neotropics. It is probable that a number of the references to *E. guineensis*, the African oil palm, refer in fact to *E. oleifera* (= *Corozo oleifera*), the American oil palm, or 'Corozo palm', which is a native of northern South America and Central America. The limited host species lists for the R.R.D. nematode reflects a lack of investigation rather than a limit to the diversity of palm flora infested. It would be of considerable value, in countries where R.R.D. is endemic, to undertake a palm inoculation study in order to establish a more complete list of those palms which could act as alternative hosts and thus reservoirs of the R.R.D. nematode. It has been suggested that some palms may act as a host of the nematode if artificially inoculated but are not hosts of the insects responsible for its spread. With the increased range of insect transmitters implicated in the spread of R.R.D. (see below and Figure 2) it would be dangerous to neglect the importance of any potential palm reservoir.

LIFE CYCLE AND SURVIVAL

Inoculation trials indicate a life cycle time for the R.R.D. nematode from egg to egg, of 9–10 days. All stages of the nematode have been recovered from the roots, the stems, and the petiolar tissues of coconut palms. In such tissues the nematode moves intercellularly, but may be found aggregated in areas where cellular breakdown has occurred. No adequate explanation has yet been provided however, for the occasional failure to recover nematodes from some regions of heavily diseased palms. A possible explanation, whereby palms infested initially in the crown lack nematodes in their bases and vice versa, does not adequately explain many failures to consistently recover nematodes from some areas of palms which have been infested for several months. Nematodes move from one region of the palm to another, but do not pass from the palm stem into the fruit. Inoculated nuts however, can support a population of nematodes and may develop their own distinctive red ring. They may thus be implicated in the transmission of the disease under conditions in which nuts are collected from the ground, or from palm chippings, infested with the nematode. There is, however, some evidence to suggest that such infestation of nuts or young seedlings does not survive to establish an infestation in the young palm as it grows.

The R.R.D. nematode can survive in fresh water films for seven to eight days and in sea water for three days, but attempts to culture them on various artificial media have failed. Survival in water may be increased by adding glucose or sucrose to the liquid.

SYMPTOMS OF R.R.D.

External symptoms of R.R.D., especially in the early stages of infestation are rarely diagnostic. A coconut palm suffering from any debilitating condition, be it a generalized nutrient deficiency, mechanical damage or death of the growing point, exhibits a range of generalized symptoms. Superimposed on such general symptoms are the specific symptoms attributable to a specific condition such as R.R.D. These differential symptoms become somewhat more apparent as the malady develops. Discoloration and drooping of leaves, breaking off of the crown, rotting of the bud or crown, generalized or localized rotting of the roots are all symptoms which from time to time have been attributed to R.R.D. While many of these symptoms are associated with this condition they can in no way be taken as diagnostic.

The golden yellowing of the leaves characteristic of the disease in its more advanced stages in JT palms in the Caribbean is not exhibited by many PT palms on the Pacific coast of America. The 'little leaf' symptom reported for the disease of Surinam and Guyana has also not been recorded outside these countries. However, Barrett in 1907 describes the little leaf symptoms on coconut palms in Trinidad in a R.R.D. endemic area and states that it is believed to be a separate and fatal condition of the palm. ('Little leaf disease' is a condition seen when a severe physiological stress is imposed on a palm.)

In Trinidad, where the coconut population is genetically more homogeneous, certain disease characteristics such as the golden yellowing of the leaves can be distinguished. With increasing heterogeneity, changing climatic and ecological conditions and plantation practices such symptoms become increasingly difficult to define. The only definitive visual symptom of R.R.D. is the presence in a transverse section of the stem of the ring of discoloured tissue, usually red in JT palms but often orange or brownish in PT palms, extending to a greater or lesser extent up or down the stem. In advanced stages of attack the discoloration extends into the central tissues of the older leaf petioles. Diagnosis however is dependent upon the recovery of R.R.D. nematodes from the tissue of the palm. The classical cylinder of red discoloured tissue is exhibited by the JT palms but the PT palms frequently exhibit a more diffuse ring or in extreme cases the discoloration of the whole central area of the stem.

In parts of Central and South America, death of palms due to R.R.D. is often attributed by the plantation workers in the more remote areas, to black palm weevil attack or, where no weevil tunnels are seen, to bud rot or lightning strikes. This explanation is given even when several palms are dying and the red ring can be distinctly seen within them.

THE TRANSMISSION OF R.R.D.

Figure 2 lists those arthropods which have been implicated in the spread of R.R.D. and gives details of their geographical distribution. There is no evidence for most of those listed that their importance in transmitting R.R.D. nematodes is anything more than a phoretic relationship and is probably restricted to those species which move directly from one palm to another. There are over 300 insect species reported in the literature to be associated with coconut palms in the Neotropics. It is possible that any of these in addition to the non-insect fauna such as rats, birds, bats, etc. could be similarly responsible for the limited transfer of nematodes or infested material from one palm to another or to the soil around such palms (see below). A number of insects pass much of their life burrowing through the tissues of the palm. With the exception of the black palm weevil and the bearded palm weevil, *Rhinostomus barbirostris*, there is at present no direct evidence that arthropods carry more than the occasional nematode inoculum between palms.

The bearded palm weevil carries nematodes both on and within the body of the adult. This weevil is important in R.R.D. transmission in Brazil and in El Salvador but is considered to be insignificant in Trinidad and Tobago where Hagley found few nematodes on bearded palm weevils that he examined in Trinidad, and in Mexico where Mendoza found none. The weevil oviposits at any point on the stem of the coconut palm and does not show any preference for young palms. The species is characterized by the size range of the adult which has often led to incorrect identification. After hatching, young larvae burrow horizontally into the centre of the palm stem and then chew their way up or down this softer central tissue. Tunnels never join even when the palm is extensively tunnelled through. It is probable that the larvae are capable of detecting chemical differences in the palm wood surrounding tunnels and avoid contact with other tunnels by avoiding this tissue. In cross-section such surrounding tissue appears to form a halo of darker coloured tissue around the tunnel. Before pupation the mature larvae burrow to the periphery of the stem where they pupate in a gallery without the formation of a cocoon and with the head pointing towards the exterior. When the insect has developed in a R.R.D. infested palm, the adult emerges infested with nematodes. Palms heavily infested with this weevil are prone to stem breaking in high winds in the region where pupation has occurred. Such emergence holes frequently become invaded by secondary pathogens including the fungus *Ceratocystis paradoxa*, resulting in the development of the typical symptoms of bleeding stem disease. *Rhynchophorus palmarum* does not favour these damaged areas for oviposition.

Two other species of *Rhinostomus*, *R. quadrisignatus* and *R. thompsoni* occur within the geographical range of R.R.D. Both these species are recorded (Vaurie, 1970) together with *R. barbirostris* in Ecuador; *R. barbirostris* and *R. quadrisignatus* are found together in Brazil, French Guiana and Peru and *R. barbirostris* and *R. thompsoni* are found together in Colombia. Considerable difficulty may be experienced in the field in distinguishing between these species since the intraspecific diagnostic features are small and based on detailed comparisons. *R. thompsoni* was described by Vaurie (loc. cit.) only in 1970. Considerable care will therefore be needed in the future in identifying the species of *Rhinostomus* involved in the transmission of R.R.D. in South America.

The black weevil palm *Rhynchophorus palmarum* L., is the principal insect transmitter of

R.R.D. in Trinidad and probably in many other parts of the Neotropics. Its absence from the Maracay region of Venezuela where R.R.D. is common confirms, as does much of the work of the Trinidad and Tobago Coconut Research Ltd., that in its absence alternative methods of transmission exist. This weevil also transmits a free-living rhabditid nematode between coconut palms.

The black palm weevil like the bearded palm weevil oviposits on coconut and other palms. In JT palms in Trinidad it does so almost exclusively in the crown, while in El Salvador and other parts of South America crown or basal oviposition may occur even in mature palms. The adult weevil is capable of drilling an oviposition tunnel, using its beak, into mature basal stem tissue of PT coconut palms.

Figure 7 compares the percentages of weevils carrying R.R.D. nematodes from various populations. The R.R.D. nematode is carried by the weevil larvae, pupae, and adults both internally and externally. Within the body of the adult weevil, nematodes are located in the gut, the body cavity and in the region of the ovipositor; while in the larvae they are located in the gut, haemocoel and tracheae. However, survival may be limited to 8–10 days within the body of the weevil. Viable R.R.D. nematodes may be passed out with the excrement of adult weevils and larvae. Griffith suggests that, in Trinidad, the spread of the nematode is only undertaken by the smaller sized weevils in a population and that these 'vector weevils' are less than 30 mm long. This character is said to be genetically transmitted and involves an enzyme system which limits the survival of nematodes in 'non vector weevils'. This size specificity for transmission has not been confirmed by work in Grenada or El Salvador where all sizes of weevils carry nematodes. The range of body lengths for weevils collected in Trinidad and Grenada is similar, however those collected from El Salvador are considerably larger.

The weevil populations from the Caribbean islands may differ from those of continental America not only in their measurements but also in their behaviour with respect to R.R.D. and coconut palms. It should also be noted that Caribbean weevils feed on the introduced JT coconut in contrast to the continental and Pacific coast populations which have more opportunity to feed on indigenous palms.

Two other beetles, suggested as transmitters of R.R.D., have a similar close relationship with the coconut palm, *Homalinotus coriaceus*, a weevil, which lives and feeds mainly on the flower stalks and young leaf stalks and *Strategus aloeus*, the American rhinoceros beetle. There are no confirmed reports of nematodes having been specifically recovered from either of these insects. Several other *Strategus* species have similar close relationships with both living and dead coconut palms, as do *Parisoschenus expositus, Melamasius hemipterus* and several other small weevils. If a phoretic relationship of the type suggested above is considered, they too may be equally involved in the spread of the R.R.D. nematode.

Considerable emphasis has been placed on the role of the black palm weevil as the transmitter of R.R.D. The evidence in the field does not support the hypothesis that this insect is the sole transmitter of R.R.D. Other insects certainly play a part as do the many other factors which bring the nematode into contact with the palm. Of the potential transmitters other than palm weevils (Figure 8) the majority depend for their effectiveness upon carrying the R.R.D. nematodes either directly, or in infected material, to the soil around the roots of the coconut palm. Nematodes can survive for sufficient time and move sufficient distances through the soil to permit them to reach and invade healthy as well as damaged palm roots. Once established in the root systems, nematodes move more rapidly towards the stem than away from it and this may result in a generalized infestation of the palm. Such root infestations however, do not always develop into a stem infection within a reasonable period of time. This failure to establish a systemic infestation in a palm following a

FIGURE 7 THE PERCENTAGE OF PALM WEEVIL POPULATIONS CARRYING R.R.D. NEMATODES

% Positive	Country	Annotation No.
9·8	Trinidad	196
10–67	Trinidad	106
35	Trinidad	72
38·5	Trinidad	168, 170
45	Venezuela	227
50	Panama	39
66	Mexico	233
72	Grenada	269, 270

FIGURE 8 FACTORS (other than identified insects) ASSOCIATED WITH THE TRANSMISSION OF R.R.D.

Factor	Annotation No.
Agricultural implements	33, 70, 119, 232
Black Vulture (*Coragyps atratus foetens*)	30
Chippings (of infected stem tissue)	84, 216, 217, 246
Coconut seedlings	33, 109
Hurricane	160
Insects	3, 30, 33, 59, 157
Irrigation water	59, 232
Lizards	30
Man	33, 70
Movement, up the stem	3
Nuts	3, 5, 33, 64, 65, 66, 109, 312
Palm fauna	3, 30, 228
Rainwater	3, 312
Rats	30
Roots, left in soil	92
Root to root transmission	90, 99, 219
Soil-borne	13, 15, 16, 33, 62, 64, 65, 66, 69, 77, 79, 85, 87, 90, 92, 99, 119, 321
Wind-borne	3, 30, 59

root infestation may indicate that the root systems of some palms possess a degree of resistance to the nematode. Such resistance may be more pronounced in certain coconut cultivars. Observations on the symptomatology and severity of attacks suggest that PT is more resistant to, or tolerant of, the R.R.D. nematode than JT. PT has proved to be a better parent than JT in producing hybrids tolerant to lethal yellowing (Whitehead, 1968; Harries and Romney, 1974) and also shows greater resistance to leaf spot (Harries, 1970). Considerable caution should therefore be exercised when extrapolating findings of disease symptoms and control from one variety of coconut growing under one set of conditions to another variety growing under the same or different conditions.

ALTERNATIVE HOST PLANTS OF THE PALM WEEVIL

The palm weevil is the principal insect transmitter of R.R.D. and although in the Lesser Antilles, its geographical range extends beyond that for R.R.D., in general it may be found wherever R.R.D. occurs. In addition to the coconut palm, many other palms and a number of other plants act as hosts for this weevil (Figure 9). It is a pest of the pineapple, the papaya and a possible minor pest of

FIGURE 9 ALTERNATIVE HOST PLANTS OF THE PALM WEEVIL, *RHYNCHOPHORUS PALMARUM* L.

Plant	Annotation No. or author
Acrocomia lasiospatha	Ballou, 1913a; Ballou, 1913b
Ananas sativus (=*A. comosus*)	59
Bactris gasipaes (=*Guilielma speciosa*=*G. gasipaes*)	Campos, 1929
Carica papaya	59, Marin Acosta, 1969; Verano, 1940
Elaeis guineensis	204, 280
Elaeis sp.	Kranz, et al, 1977
Gynerium saccharoides	Verano, 1940
Jaracatia dodecaphylla	Bondar, 1922
Livistona sp.	Kranz, et al, 1977
Mangifera indica	59
Mauritia flexuosa	203, 204, 280
Maximiliana maripa	203, 204, 280
Musa paradisiaca normalis	59, Dean; Kranz, et al, 1977
Musa paradisiaca sapientum	Dean
Orbignya cohune (=*Attalea cohune*)	58
Phoenix sp.	Kranz, et al, 1977
Saccharum officinarum	59, Cleare, 1941; Verano, 1940

sugar cane. In El Salvador, larvae and pupae occur in the stem of the plantain (*Musa paradisiaca sapientum*), the cocoons being constructed, in the stem, from the fibrous tissue of the plantain and, in the soil below cut stems, from plantain stem fibre and grass fibres. Pupation in cocoons constructed from grass roots in the soil below cut coconut palm stems has also been recorded. In addition, larvae have also been seen feeding in banana stems. Mango has also been suggested as an alternative host, although larval feeding here is probably restricted in the fruit. A South American grass (*Gynerium saccharoides*) and a wild Brazilian papaya (*Jaracatia dodecaphylla*) have also been reported as alternative hosts. *Phoenix* sp., *Livistonia* sp. and *Elaeis guineensis*, palms which are not native to the Neotropics, are also listed as hosts. It is probable that *E. oleifera* (= *Corozo oleifera*) is also a host. Many other alternative hosts of the black palm weevil probably exist among the wild palms and other jungle flora which serve as reservoirs for the weevil. Any control measure aimed at controlling the palm weevil and thus R.R.D. must take into account the proximity to the coconut plantation of such alternative hosts.

CONTROL

BIOLOGICAL. Biological control agents do not, at present, offer any potential for R.R.D. control. One report exists of a fungus killing R.R.D. nematodes under laboratory conditions.

PHYSICAL. Various practices aimed at isolating the infested coconut material within a coconut plantation have been recommended. These include burial or burning of infested material, cultivation of the soil, ditching or trenching, fallowing, heat sterilization of the soil, control of irrigation, natural sterilization of the soil as a result of dry season drying out, phytosanitary methods and the physical removal of infested material from the plantation. If soil transmission were the sole means of spread of the disease, these techniques would be sufficient but in the presence of dynamic transmitters such as insects and man, additional control measures must be considered. Physical control measures centred around plantation hygiene clearly play a major part in limiting the spread of infestation by removing a large proportion of the potential inoculum from the environment. They are indeed an essential part of any proposed integrated control programme against R.R.D. but are not sufficient alone.

CHEMICAL. Direct control of R.R.D. by soil fumigation or sterilization is limited to the extent to which the nematode itself inhabits the soil environment. It has been argued above that soil transmission of R.R.D. must occur, if only to a limited extent. It must therefore be accepted that soil fumigation will have the same limited value in controlling the spread of the disease.

The application of systemic nematicides either to the soil around coconut palms, by injection into roots or stem, or by introduction into the axils of leaves in the crown of the palm has been shown to have only a limited effect on a systemic infestation of the nematode. Roots challenged with the nematode can be protected, for a limited period, by the application of systemic nematicides. Such systemic nematicides, however applied, have had no long term effects on field infestations in plantations in Trinidad. Quantities of nematicide lodged in the axils of leaves killed nematodes which were introduced into these axils, but had no long term effects upon systemic infestations and the labour involved, at plantation level, of applying pesticides to every leaf axil of every palm makes such a procedure impractical.

The use of systemic nematicides must be further explored. Despite the partial blockage of vascular tissue resulting from infestation of the stem by the R.R.D. nematode, dyes will readily move up an infested palm stem. In a recent trial in El Salvador (Dean, unpublished) dyes moved 7·5 metres up heavily R.R.D. infested, 35 year-old, palms in less than 6 days, completely colouring the tissue in the area of the crown. The downward movement of the dye was very limited and its distribution was not uniform in the lower parts of the stem immediately above the point of injection. Treatment by this method may prove to be more effective in controlling crown attack by palm weevils and, although at present uneconomical, could provide prophylactic protection against the R.R.D. nematodes introduced by the weevil into the crown of the palm.

CHEMICAL ELIMINATION OF INFESTED PALMS. An integral part of plantation hygiene is the elimination of infested palms. Much work has been undertaken in Trinidad on the use of herbicides to poison palms rapidly in such a way as to make them unattractive to the palm weevil and to kill the nematodes which they are harbouring. Palms so killed dry out more rapidly thus enabling them to be burned sooner.

CONTROL OF THE INSECT TRANSMITTERS. Methods for the direct control of the R.R.D. nematode have so far proved completely ineffectual in limiting its spread throughout coconut plantations in all parts of the Neotropics. It has therefore become necessary to attempt to control those insects, particularly the black palm weevil, which are known to be spreading the nematode. Work has continued almost exclusively on the control of the black palm weevil, with occasional reference to the bearded palm weevil. Several possible biological control agents have been recorded for the palm weevil (Figure 10). Smith (1974) has also suggested trials with viruses similar to those successfully used in the biological control programme against *Oryctes rhinoceros* in Oceania. While insect predators including those listed in Figure 10 may limit populations of palm weevils none has yet proved to be sufficiently effective to warrant a control programme based on its action. The activity of the ants which enter the burrows of the weevils in coconut palms in El Salvador and drive out the larvae would bear further study as would the bacterium reported to kill weevils in Trinidad.

Systemic insecticide treatment of palms and the application of insecticides to leaf axils, while possibly killing a number of insects, had little effect upon overall population levels, and no effect in reducing levels of R.R.D. in infested plantations in Trinidad. The only technique which has had a measure of success involves the use of traps based on the attractiveness of coconut tissue to the black palm weevil. Several modifications to the simple split-log trap have been used. Only those incorporating the use of an insecticide will effectively reduce populations of the weevil and such traps incorporating an attractant insecticide have reduced weevil populations on plantations in El Salvador. These trials also indicated that other insecticides applied to traps were repellant to the insect. Several trials in Trinidad comparing the attractiveness of R.R.D. infested and uninfested coconut tissue proved inconclusive but trials with other products proved more effective. Boonsom and Uthai (1975) showed that a pheromone was involved in the attraction of *Rhynchophorus vulneratus* in Thailand. Dean and Velis (unpublished) have shown a similar pheromone attraction in *Rhynchophorus palmarum* in El Salvador. Isolation of such a pheromone may provide a very valuable attractant for monitoring population levels and for the possible control of the palm weevil.

BREEDING FOR RESISTANCE. No breeding programme has so far been established for the production of varieties of coconut palm resistant to R.R.D. The varieties: Ceylon Tall, Jamaica Tall, Malayan Tall (F.M.C.), Rennell Island Tall, Solomon Island Tall, Panama Tall, all three colour lines of the Malayan Dwarf and, in Venezuela, 'Nacional' (probably a local breeding line of PT) are all susceptible to the disease. The 'varieties', Carib in Venezuela, Green Spanish in the Caribbean, Cockerite in Guyana, some PT in El Salvador and 'Manila' in Ecuador have been reported to show resistance or greater tolerance to the disease in areas where it is endemic. It is difficult to identify most of these so called 'varieties'. It is probable that the first three are local breeding lines of the JT coconut, which itself is generally the most susceptible variety to most Neotropical coconut diseases; PT in El Salvador is probably of relatively ancient and isolated origin while Smith (1974) suggests that 'Manila', which is a dwarf variety occurring in two colour lines, green and red (called yellow in Ecuador), may be of Indian origin rather than being from Malayan Dwarf stock, in that it differs in several characters from the latter.

Wherever coconut plantations are heavily attacked by R.R.D., individual palms are seen which appear to have 'resisted attack'. If the R.R.D. continues for some time they too generally succumb. However, there are locally well recorded examples of individual palms surviving in otherwise decimated plantations. These reports justify the optimism that if a wide ranging collection and breeding programme could be established resistant lines could be developed. It is unfortunate that,

FIGURE 10 POSSIBLE BIOLOGICAL CONTROL AGENTS FOR THE PALM WEEVIL

Agent	Annotation No. or author
Ants	50
Histerid Beetle	Urich, 1915
Micrococcus agilis	160
Neoaplectana (DD–136) sp.	23
Paratheresia (Parabillaea) rhynchophorae (=*Parabillaea rhynchophorae*)	Blanchard, 1937; Bennett and Maharaj, 1969; Candia and Simmonds, 1965
Rhynchopolipus rhynchophori (=*Tetrapolipus rhynchophori*)	Ewing, 1924; Husband and Flechtmann, 1972
Uropodine	50
Xanthopygus cognatus	307

due to lethal yellowing, the extensive germ plasm reserves in Jamaica cannot be utilized as a source for such material.

INTEGRATED CONTROL. The present evidence indicates that no single control method will limit the spread of R.R.D. Between 1918 and 1920, Nowell in the first papers on R.R.D. implicated the black palm weevil in the transmission of this disease in addition to soil transmission. He also suggested the use of a trapping programme for the control of the weevil using split-log traps, advocated plantation hygiene and the isolation and destruction of all infested material and advised that the only hope for control of the disease lay in prevention rather than in cure. At the present time, nearly 60 years later these same recommendations for an integrated control approach by the isolation and destruction of infested material and the trapping of the insect transmitters are all that we have to offer the coconut grower. A sad reflection on the state of our knowledge of a disease which threatens the continued production of both coconut and palm oil in the Neotropics.

ADDENDUM

The following are additions to Figure 9 (p. 15)

Acrocomia sclerocarpa	Lepesme, 1947
Guilielma sp.	Lepesme, 1947
Roystonia oleracea	Lepesme, 1947
Sabal umbraculifera	Lepesme, 1947
Syagrus coronata (= *Cocos coronata*)	Lepesme, 1947
Syagrus romanzossiana (= *Cocos romanzossiana*)	Lepesme, 1947
Syagrus schizophylla (= *Cocos schizophylla*)	Lepesme, 1947

The following is an addition to Figure 10 (p. 17)

Oxysternus maximus	Lepesme, 1947

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Notes on Annotations

1. In the text of the annotations, comments between parentheses ( ) are the opinion of the editor with the exception of references to taxa and authorities for the scientific names of organisms.

2. The nematode *Rhadinaphelenchus cocophilus (=Aphelenchoides cocophilus=Aphelenchus cocophilus)* is referred to in the text by the name used by the author of the article.

3. The following abbreviations and common names are used throughout the text:
R.R.D.=Red Ring Disease
R.R.D. nematode=*Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960
Palm Weevil=*Rhynchophorus palmarum* L.

4. When the Latin name and the common name for a palm species are both given by an author, only the former is indexed. No attempt has been made to give the Latin name where only the common name is given. In these cases the common name, as given by the author, is indexed.

5. The language of the original text of an abstracted article is that of the title. An English translation is given within brackets [ ] immediately after the title.

6. Where possible an author has been associated with each article. Where an author cannot be attributed, the paper is included under the name of the organization or the country of origin.

7. Abstracts taken from the Annual Reports of the Trinidad and Tobago Coconut Research Limited and certain other reports are more detailed than others although in many cases the work reported was subsequently published in part elsewhere. It is felt that the additional details given in these reports and the difficulties which would be experienced in many countries in obtaining copies of them justifies the duplication.

8. 'Infection' and 'infestation' are variously used by authors. An attempt has been made to maintain the word used by the author concerned.

Annotations from the Literature

1—ALCOCER GOMEZ, L., 1955. Enfermedad de la palma de coco conocida como 'anillo rojo'. [The disease of the coconut palm known as 'red ring'.] *Fitofilo, Mexico,* **8** (11), 8–11.

2—ASHBY, S. F. A. 1921. Some Recent Observations on Red Ring Disease of the Coco-Nut. *Agricultural News,* **20**, 334.

The author refers briefly to the known history of the disease. Tests on the desiccation resistance of the nematode *Aphelenchus cocophilus* showed that air dried larvae died after 15 hours in the presence of tissue fragments and after 6 hours in their absence. Nematodes swam in water at 1 in/min (25 mm/min) or through droplets on a glass plate at 0·33 in/min (8·4 mm/min). They could climb vertically up wooden spills or moist glass surfaces in a saturated atmosphere. Larvae retained their power of active movement for one week in water, for 3 days in 2·5% saline or sea water and for 2 days in 10% sodium bicarbonate. Sluggish movement continued for 4 days in 10% saline. The effect of salt on movement may be the basis for control measures.

3—ASHBY, S. F. 1921. Some Recent Observations on Red Ring Disease of the Coco-Nut. *Agricultural News,* **20**, 350–351.

A continuation of the observations in Grenada on the biology of the nematode causing R.R.D. in coconuts. Palms under 4 and over 10 years are rarely attacked. Inoculated 1- and 2-year-old palms become infested; they possess no special resistance. Green nuts inoculated at the stem end developed red rings and contained nematodes. Inoculated seedlings did not develop symptoms or stem infestations but their root systems had become infested with all stages of the nematode. Bags of salt hung in the crown did not prevent 2 inoculated palms from becoming infested in the crown region; larval root infestations were also recorded in these palms. The probable breeding places of the nematodes are the red ring area, the leaf stalks and the upper part of the stem. Nematodes pass into the roots from the stem. Nowell and the author found only larvae in the roots. Under favourable humidity the larvae should be able to climb the stem or up leaves touching the ground to reach the crown. Spread of the nematodes also occurs in wind-blown tissue fragments from diseased palms and by palm weevils and scavenging insects moving from such palms. Dead and dying palms should be destroyed rapidly. Nematodes are also spread by rainwater and may be carried in damaged nuts which they have entered. Further experiments with salt and banding the palms with tar and tallow are under way.

4—ASHBY, S. F. 1922. Experiments on the Red Ring Disease of Coco-Nut in Grenada. *Agricultural News,* **21**, 94–95.

Experiments using bags of salt in the crowns of palms and salt turned into the soil around palms failed to prevent successful infestations of palms inoculated in the crown and soil respectively. Some crown-inoculated palms also developed root infestations. Full details of the experiments are given. Of 8 palms banded with a 2:1 tar:tallow mixture, 5 became infested in the stem and two others showed root infestations. A hurricane during the trial is said to have interfered with the results.

5—ASHBY, S. F. 1924. Red Ring Disease of the Coconut. *Proceedings of the 9th West Indian Conference, Jamaica,* 164–172.

A historic paper in which Prof. Ashby in the presence of Mr Nowell (cf abst. No. 248) describes the current state of knowledge on R.R.D. Much of the detail is taken from the work of the latter. Ashby shows that salt added to the crown or surrounding soil did not prevent infection and that nematode populations could be sustained in green coconut fruits, a red ring being produced in the fruit. This is suggested as one of the probable means of transmission. It is confirmed that the nematode is not transmitted to the fruit from the palm. R.R.D. is widespread in Central America where infections are frequently seen commencing at the base of the palm.

Nowell commented: R.R.D. is a disease of adolescent coconuts; it is a serious problem that could spread rapidly and kill palms quickly; the external symptoms are unrecognizable until an advanced stage of the disease; and quarantine measures are essential especially with the knowledge that nematodes can survive in nuts which have been in contact with contaminated soil. Nowell did not agree with Ashby with regard to root infections. Alternative hosts for the nematode include the Gru-Gru and the Cabbage Palm. The former palms, 8–10 feet tall, were totally destroyed 3 weeks after inoculation with nematodes.

6—BAIN, F. M., FEDON, C. S. A., 1951. Investigaciones sobre anillo rojo del cocotero. [Research on red ring of coconut palms.] *Agronomia Tropical, Maracay,* **1** (2), 103–130.

R.R.D. of coconut palms associated with the nematode *Aphelenchus* [*Aphelenchoides*] *cocophilus* is serious in Venezuela. Bain & Fedón review the published work on the disease, describe the symptoms and give an account of their inoculation experiments. Fruiting and non-fruiting palms of different ages were inoculated by the placing of infested material either around the roots or in the axils of the crown leaves. Results showed that infestation is not by way of the roots but takes place in the leaf axils; symptoms became obvious after about 2 months. The nematodes do not pass from palm to palm by way of the soil but are

carried by ants and by *Rhynchophorus palmarum*. The ants which are normally found on plants in flower are common in the leaf axils of palms at the most susceptible age and are said to travel from palm to palm in search of food. The problem of control of R.R.D. is an entomological one, it being necessary to control the ants as well as to burn infested palms. One palm in the experiments showed a high degree of resistance to the disease.

7—BANGUERA, R. L., SANCHEZ POTES, A., 1971. Erradicacion quimica de palmas de cocotero afectadas por el anillo rojo (*Rhadinaphelenchus cocophilus* Cobb, Goodey). [The chemical eradication of coconut palms affected by red ring disease (*R. cocophilus*).] *Revista Instituto Colombiano Agronomica*, **6** (4), 339–344.

R.R.D.-infected coconut palms could be killed by injection of cacodylic acid at 20–30 ml, picloram + 2,4-D at 50 ml or sodium arsenate at 70 ml/palm.

8—BANGUERA, R. L., SANCHEZ POTES, A., 1972. Efectividad de algunas sustancias quimicas para la erradicacion de palmas de cocotero afectadas por el anillo rojo (*Rhadinaphelenchus cocophilus*) Cobb, Goodey. [Efficacy of various chemicals in killing coconut palms infected with red ring (*R. cocophilus* Cobb, Goodey.)] *Acta Agronomica, Palmira*, **22** (1), 33–42.

Cacodylic acid, picolinic acid with 2,4-D and sodium arsenate were used to kill *R. cocophilus*-infected palms in coconut plantations along the Colombian Pacific coast. Cacodylic acid at 20 to 30 ml/palm was the most effective since it was highly nematicidal as well as phytotoxic. The other two chemicals were effective at 50 ml/palm and 70 ml/palm, respectively.

9—BARRENCHE, J. A., 1963. Campaña del cocotero en Urabá. Recomendaciones a los agricultores. [The coconut campaign in Uraba (Colombia). Recommendations to the farmers.] Instituto de Fomento Algodonero. División de Oleaginosas, Bogotá, Colombia, 33p.

10—BARRETT, O. W., 1907. Notes upon miscellaneous crops. Coconuts. *Proceedings of the Agricultural Society of Trinidad and Tobago*, **7**, 303–304.

The fungus *Botryodiplodia* is associated with palms dying from root disease (R.R.D.), which accounted for 95% of the palm deaths in Trinidad. Very few palms are attacked by *Pestalozzia* (*Pestalotiopsis*) and fewer by bud rot. A number of palms were affected by an unknown physiological condition which produced a pronounced shortening of the rachis and leaflets with a slight curling of the latter (?Little Leaf); the condition is believed to be fatal. Recommendations are made for the use of a leguminous cover crop and for a study of the life cycles of the fungal parasites of coconuts.

11—BELIZE (British Honduras), Ministry of Agriculture, 1953. *Report of the Department of Agriculture for the year 1952*, p. 5.

R.R.D. is reported in coconuts in Belize.

12—BELIZE (British Honduras), Ministry of Agriculture, *Report of the Department of Agriculture for the year 1954*, p. 7.

R.R.D. is reported in coconuts in Belize.

13—BELIZE, 1977. *Growing Coconuts*. Crop Development Division. Unnumbered Bulletin of the Ministry of Agriculture and Lands, Belmopan, 12pp.

R.R.D. is the major disease problem of coconuts in Belize. The nematodes bore into the roots and up into the trunk, killing the palm 3–4 months later. There is no cure for infected palms which should be buried. A trench should be dug around the area of infected palms and the soil treated with a nematicide. Nematodes are spread by the palm weevil whose control can help to limit the spread of the nematode.

14—BLAIR, G. P., 1961. *Report of the Botanist, Red Ring Research Scheme, Ministry of Agriculture, Central Experiment Station, Trinidad and Tobago*. 15 pp.

15—BLAIR, G. P., 1963. *Red Ring Disease of the Coconut Palm incited by* Rhadinaphelenchus cocophilus *(Cobb, 1919), Goodey, 1960*. Unpublished Ph.D. thesis, University of Wisconsin, 90 pp.

The following is essentially the author's summary: (see also abst. No. 16). *R. cocophilus* incited R.R.D. when inoculated artificially in suspension into stems, leaves, or roots of coconut palms between 3 and 10 years old. Nematodes also penetrated intact tissue of leaf axils, petioles and roots. External symptoms appeared 40–70 days after inoculation and palms were dead in 6–8 weeks after symptoms first appeared.

The nut does not become naturally infested but green nuts were successfully infested artificially both on palms and in the laboratory; the symptomatology is described. The nematodes did not pass from infested to healthy nuts through the fruit stalk.

R. cocophilus is found both inter and intracellularly in the ground parenchyma of infested tissue. Some cells disintegrate forming cavities in which nematodes are abundant. Many of the cells in the infested tissue lose their contents. The nematodes tend to migrate to areas with living cells. Adults and eggs are in greater numbers in the crown region of palms where lesions terminate in elongate streaks and dots of orange-coloured tissue.

Nematodes do not invade or directly damage xylem vessels. However, the vessels which pass through the discoloured areas become occluded with tyloses.

Nematodes did not survive longer than five days in artificially infested soil at all moisture levels. No specimens of *R. cocophilus* were recovered from the soil in coconut fields away from diseased palms nor from cacao, citrus and sugar cane fields. It is unlikely that the nematode survives in soil in nature for long periods and the root does not appear to be a common site for initial infestation.

The leaf axils appear to be the most frequent site for initial infestation. They are most susceptible when internodes in the crown region are longest, about the age of 4–7 years. The incidence of R.R.D. is greatest also at this age. Specimens of *R. cocophilus* have been recovered from the palm weevil, *Rhynchophorus palmarum* L., which has been shown to transmit the disease.

A solution of EN 18133 injected into stems of diseased palms killed a high percentage of nematodes throughout both stems and leaves, but when applied to the soil it did not reduce natural infestation under field conditions.

D–D and weedicide injected into palms killed nematodes and rapidly killed and desiccated the palms.

16—BLAIR, G. P., 1963. Red ring disease of the coconut palm incited by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960. *Dissertation Abstracts*, **24** (1), 20–21.

External symptoms of R.R.D. appeared 40 to 70 days after diseased tissue or a suspension of *R. cocophilus* was placed in holes in the stem, leaves or roots of 3- to 10-year-old coconut palms. The palms died 6 to 8 weeks after the symptoms first appeared. The coconut fruit does not become naturally infested but green nuts were successfully infested artificially both on the palm and in the laboratory. Nematodes did not pass from infested to healthy nuts through the fruit stalk. Adult nematodes and eggs are present in greatest numbers in the crown region of palms. Because xylem vessels passing through discoloured areas become occluded with tyloses, the water-conducting system of infested palms becomes inefficient. It is unlikely that *R. cocophilus* survives in soil in nature for long periods. Leaf axils appear to be the most frequent site for initial infestation. *R. cocophilus* have been recovered from *Rhynchophorus palmarum*, a suspected vector. This palm weevil has been shown to transmit the disease. Injection of EN 18133 into the stems of diseased palms killed a high percentage of nematodes in both stems and leaves; when applied to the soil it did not reduce natural infestation. When this nematicide was applied with sand to the leaf axils, it completely protected palms against infestation when they were inoculated one week after treatment. D–D and weedicide (sodium and potassium arsenite) killed nematodes in diseased palms when applied in holes on opposite sides of the stem.

17—BLAIR, G. P., 1964. Red ring disease of the coconut palm. *Journal of the Agricultural Society of Trinidad and Tobago*, **64** (1), 31–49.

The characteristic ring of discoloured tissue in the stems of coconut palms was fully developed 25 days after inoculation with *R. cocophilus*. Yellowing of the leaves started 5 days later. The nematodes were absent from xylem vessels which were, however, occluded by the formation of tyloses in the discoloured area. The maximum length of survival of the nematode in soil was found to be 15 days. Nemafos (thionazin) apparently protected the palms when applied monthly to leaf axils and was not phytotoxic. *Roystonea oleracea*, the cabbage palm, was established as a host of *R. cocophilus*.

18—BLAIR, G. P., 1965. *Red Ring Disease. The need for further experiments on control.* Red Ring Research Division. Ministry of Agriculture, Trinidad and Tobago. 12pp

19—BLAIR, G. P., 1966. The use of immature nuts of *Cocos nucifera* for studies on *Rhadinaphelenchus cocophilus*. *Nematologica*, Year 1965, **11** (4), 590–592.

Harvested immature nuts of *Cocos nucifera* are convenient and suitable for studies on *R. cocophilus*. They are readily available and are small in size permitting most of the infested tissue to be examined for nematodes. Immature nuts were inoculated in the laboratory with eggs of *R. cocophilus*. After 9 to 10 days adults and eggs were recovered, indicating that the nematode had completed its life-cycle in that time.

20—BLAIR, G. P., 1966. Advances in Red Ring Research. *Journal of the Agricultural Society, Trinidad and Tobago*, **66**, 127–130.

Xylem vessels in R.R.D.-infected coconut palms become blocked, impeding water passage. Nemafos proved an effective nematicide but was too expensive. The current investigations on control of R.R.D. include the use of bitumen to seal up the cracks in healthy palms. The nematode life cycle was of 9 days duration, the shortest for any plant parasitic nematode. Adults and eggs were confined to a small region at the top of the red ring. CO_2 content of diseased palms was 3 times that of healthy palms. This concentration was said to inhibit the development of the nematode in the stem. The cause of this high CO_2 concentration was the blockage of xylem vessels. Some nuts were highly resistant to the disease; there is ample evidence that such resistance is inherited and is of a biochemical nature. Susceptibility to R.R.D. also depends upon morphological features including the size of internodes and amount of cracking of the palm.

21—BLAIR, G. P., 1969. Studies of red ring disease of the coconut palm. In: *Proceedings of*

the Symposium on Tropical Nematology, 1967, University of Puerto Rico, 89–106.

A detailed account is given of R.R.D. of coconut palms caused by *R. cocophilus*. The chief means of infestation is shown to be through the activities of the weevil *Rhynchophorus palmarum* which carries nematodes from infested palms to the primary site of infestation in the crown, where the nematodes can enter through cracks in the stem. They then move down and spread around the stem in the outer layers of the central cylinder. Their migration and development are considered to be governed by the concentration of CO_2 in different regions of the stem. The histopathology of diseased palm trees and control of red ring disease are briefly reviewed. The colour of the ring probably results from high polymer anthocyanins.

22—BLAIR, G. P., 1969. First International Congress of Plant Pathology. Abstracts: *Nematology*. *PANS*., **15** (2), 267.

R. cocophilus, the cause of R.R.D. of coconuts is attracted to CO_2, high concentrations of which, however, inhibit the larvae maturing. Blocked xylem vessels cause an increase in CO_2 which limits the downward spread of the infection.

23—BLAIR, G. P., 1969. The problem of control of red ring disease. In: Peachey, J. E. (Ed.) *Nematodes of tropical crops*. Technical Communication of the Commonwealth Bureau of Helminthology, Number 40, 99–108.

The dissemination and control of R.R.D. of coconut caused by *R. cocophilus* are reviewed. The principles on which control of this disease is based are listed and discussed, and the need for resistant varieties is stressed.

24—BLAIR, G. P., 1970. Studies on red ring disease of the coconut palm, *Oléagineux*, **25** (1), 19–22; (2), 79–83.

A detailed account is given of the sites of entry of *R. cocophilus* into the coconut palm and the distribution and life cycle of the nematodes in relation to the anatomy of the palm and the CO_2 and O_2 gradients in the tissues. Susceptibility to R.R.D. varies amongst coconut palms and is correlated with morphological features of the crown. Control measures are discussed.

25—BLAIR, G. P. & DARLING, H. M., 1968. Red ring disease of the coconut palm, inoculation studies and histopathology. *Nematologica*, **14** (3), 395–403.

In Trinidad, coconut, *Cocos nucifera*, and cabbage palm, *Roystonea oleracea*, aged 4 to 7 years, developed R.R.D. and died following inoculation with *R. cocophilus* through wounds in their stems and roots.

When roots of 12-year-old coconut palms were inoculated with *R. cocophilus*, they became infested and decayed but palms did not die from the disease. *R. cocophilus* incited R.R.D. in both coconut and cabbage palms 3 to 7 years old when inoculum was placed on roots which were not artificially damaged. *R. cocophilus* also incited R.R.D. in the coconut palm but not in the cabbage palm when inoculum was placed in their leaf axils. *R. cocophilus* occurred mostly in discoloured ground parenchyma tissue and in smaller numbers in the adjacent white parenchyma. Nematodes were present only intercellularly in the upper part of the stem where lesions were discrete, but in the discoloured zone they were also present intracellularly and parenchyma tissue was damaged. A few cells in such areas were completely destroyed, forming microscopic cavities which were teeming with *R. cocophilus*. Though the nematode was not found in the vascular tissue, xylem vessels in the discoloured area were found to be occluded with tyloses. *R. cocophilus* appeared to enter coconut palms through cracks in the stem near leaf bases. Suggested approaches to control are to seal such cracks mechanically or to place a granular preparation of a nematicide in leaf axils.

26—BONDER, G., 1945. Nova e Grave Ameaca aos Coqueirais Brasileiros. [New and serious threat to Brazilian coconuts.] *O Campo*, **16** (182), 71–72.

27—BONDER, G., 1945. Nova e Grave Ameaca aos Coqueirais Brasileiros. [New and serious threat to Brazilian coconuts.] *O Campo*, **16** (183), 15–19.

28—BRATHWAITE, C. W. D.; SIDDIQI, M. R., 1975. *Rhadinaphelenchus cocophilus*. *C.I.H. Descriptions of Plant-parasitic Nematodes*, Set 5 (No. 72), 4 pp.

A detailed taxonomic description of *R. cocophilus* is given. The authors quote Esser (unpublished) as saying that the vulval flap in the female as described by Goodey (abst. 143) may not be present, having been seen by Esser in only 1 out of 12 specimens. Thorne (abst. 291) and Nickle (abst. 239) describe a fourth pair of papillae in the male, located ventro-laterally behind the anus; Cobb (abst. 38) and Goodey (abst. 143, 144) do not report these. The authors state that these are very obscure and often not detectable. Sexual dimorphism is seen in the tails of the fourth larval stage, whose shapes also differ from those of the earlier larval stages. The genus may belong to a sub-family Parasitaphelenchinae. Distribution is widespread in the Caribbean and Latin America: St Vincent, Grenada, Trinidad and Tobago, Belize, Brazil, Colombia, Costa Rica, Equador, El Salvador, Guyana, Honduras, Mexico, Panama, Surinam and Venezuela. Host plants are *Cocos nucifera, Elaeis guineensis, Roystonea oleracea, Acrocomia aculeata, Mauritia flexuosa* and *Maximiliana maripa*. The biology, host parasite relations and control measures are also discussed from the literature.

29—BRITON-JONES, H. R., 1931. Trinidad plant diseases. Notes on some diseases of main crops in Trinidad. *Tropical Agriculture, Trinidad,* **8** (11), 300–302.

Incidences of R.R.D. in Trinidad are greater on plantations established on previously uncultivated land than on old sugar cane land although, in the absence of the disease, palms grow better on the former. Weeds acting as alternative hosts for R.R.D. nematodes are suggested as a possible explanation for this situation. The majority of palm losses are said to be due to Bronze Leaf Wilt. (Bronze Leaf Wilt was an ill-defined condition of coconuts now recognized variously as Lethal Yellowing, Bud Rot or occasionally R.R.D. The former occurs only in the northern Caribbean area where R.R.D. does not occur.)

30—BRITON-JONES, H. R., 1940. *The diseases of the coconut palm.* Baillière Tindall and Cox, London. 176 pp. (R.R.D., pp. 91–110).

This book was completed before the author's death in 1936 and was revised for publication by E. E. Cheesman. R.R.D. occurs in Grenada, British Guiana (Guyana), British Honduras (Belize), Panama, Trinidad and Tobago, and Venezuela. The external and internal symptoms are described based on Nowell (abst. 247), the former closely resembling those of Bronze Leaf Wilt disease. If the palm recovers, the disease was Bronze Leaf Wilt! It is suggested that *Aphelenchus cocophilus* may be carried by the fauna visiting the palm including: various insects, tarantulas, spiders, rats, lizards, the Black Vulture (*Coragyps atratus foetens* Lichtenstein) and possibly by the wind. R.R.D. is much less common on palms growing on sugar cane land than on secondary bush or uncultivated land. The current, unsatisfactory method of control is by digging isolation trenches. Cultivation, weed control and fertilizer applications are recommended for young palms from 3–7 years old, i.e., through their 'susceptible period'. Artificial fertilizers are more satisfactory than leguminous cover crops, to counteract the effects of the disease on the palm.

31—CABRERA, C. J., 1965. El anillo rojo del cocotero del Pacifico. [Red ring of Pacific coconuts.] *Agricultura tropical, Colombia,* **21** (9), 481–484.

R.R.D., which is endemic throughout Central and South America, is known to have existed in Colombia at least as far back as the memory of the growers. The disease is transmitted by *Rhynchophorus palmarum* and is followed by attacks by secondary bacteria. The nematode is very resistant to chemical control. Removal and burning of infected palms and control of the insect transmitters with insecticides are the means of control.

32—CARR, T. W. A., 1970. Methyl bromide fumigation of red ring diseased coconut trees. 1. Preliminary tests for nematicidal and insecticidal effect. *Journal of the Agricultural Society of Trinidad and Tobago,* **70** (4), 431–438.

Coconut palms infected with *R. cocophilus* and its vector *Rhynchophorus palmarum* were fumigated with Dowfume MC–2 (methyl bromide plus chloropicrin). The degree of penetration of the gas into the diseased tissues was very good and nematodes and weevils (adults and larvae) were killed. Further investigation into the simplest method of fumigation continues.

33—CHAVES BATISTA, A., 1948. O 'anel vermelho' do coqueiro e a fumigação do solo com D–D. [The 'red ring' of the coconut palm and soil fumigation with D–D.] *Boletim da Secretaria da Agricultura, Pernambuco, Brazil,* **15** (3–4), 356–387.

R.R.D. of coconut palms in Brazil was first recorded in 1936, and by 1943 had become an important disease in the extensive plantations of the north-east. Batista describes the symptoms of the disease and says that for diagnosis the causal organism, *Alphelenchoides cocophilus*, must be recovered.

The nematode may be in any part of the plant from roots to leaves and nuts, but disease symptoms are shown only when it is in the crown or the leaf bases. The biology of the nematode is discussed and it is suggested that the disease is caused by toxic secretions produced by the parasites in feeding. Dissemination of the parasites is said to be by insects (*Rhynchophorus palmarum* and possibly *Homalinotus coriaceus* and *Rhina barbirostris*), by coconut seed and seedlings, by agricultural implements and by man: spread within a plantation is thought to be by migration of the nematodes in the soil. For control of the disease, all infected plants must be burnt; soil fumigation with D–D at 400 lb per acre (449·5 kg/ha) over a 50-metre radius is recommended. Healthy plants should be treated with insecticide to deter the insect vectors. Plantations on new land should be made with healthy stock after the soil has been fumigated with D–D.

34—CHILD, R., 1964. *Coconuts.* Tropical Agricultural Series, Longmans, London. 216 pp.

Rhynchophorus palmarum L., is the vector of R.R.D. The distribution and symptoms of R.R.D. are taken from some of the literature. The disease is said not to occur in Guyana. It can be controlled by the burning of all infested material.

35—CHILD, R., 1974 (2nd Edition) *Coconuts.* Tropical Agricultural Series, Longmans London. 335 pp.

The symptoms and distribution of R.R.D. are described from a limited review of the literature. *Rhynchophorus palmarum* is said to be the vector of the disease. The population of nematodes is said to be 66,000/m of trunk. Control measures recommended include the removal of all infected material and its destruction by burning, the control of the

vector weevil and the use of soil fumigation which may reduce the incidence of the disease. Other pests, diseases and problems affecting coconuts throughout the world are discussed in addition to chapters on all other aspects of coconuts.

36—CHITWOOD, B. G., 1935. Nomenclatorial notes. 1. *Proceedings of the Helminthological Society of Washington,* **2** (1), 51–54.

Amongst other designations of type species for various nematode genera, Chitwood designates *Aphelenchoides* (C) *ormerodis* Ritzema Bos 1891 = *Aphelenchoides parietinus* (Bastian 1865) as the type species of *Chitinoaphelenchus*. This precedes Chitwoods later erroneous attempt (see abst. 43) to designate *Aphelenchoides cocophilus* as the type of that genus. (See also abst. 144.)

37—CHRISTIE, J. R., 1959. *Plant nematodes their bionomics and control.* University of Florida Press, pp. 149–151.

Aphelenchoides cocophilus (Cobb, 1919) Goodey, 1933 is an endoparasite of the coconut palm, the oil palm and date palm, *Phoenix dactylifera*. The symptoms of R.R.D. and details of some experimental work are described. Reference is made to a report of this nematode on oil palm in the Belgian Congo (never subsequently confirmed). Its distribution extends through parts of the Caribbean islands and the neighbouring mainland.

38—COBB, N. A., 1919. A Newly Discovered Nematode (*Aphelenchus cocophilus*, n. sp.) connected with a Serious Disease of the Coco-nut Palm. *West Indian Bulletin,* **17** (4), 203–210.

This paper contains a detailed taxonomic description of the nematode provided from alcohol and formalin fixed coconut tissue sent by Nowell from Grenada. Control measures are recommended based on incomplete information (Cobb understood this to be primarily a root disease). The distribution of the nematode in the roots is discussed as are the needs for further research.

39—COBB, N. A., 1922. A Note on the Coconut Nema of Panama. *Journal of Parasitology,* **9**, 44–45.

The nematode, belonging to the genus *Aphlenchus,* infects the roots and passes into the stem. The disease is spread rapidly and is very serious in the Caribbean area. Palms 4–7 years old are most susceptible. 50% of coconut weevils carried nematodes; these weevils are attracted to the ethereal odour of coconut tissue. Nematodes were not found in the intestines of weevils. Old palms and those close to the sea are less affected. Nematodes are said to be phototropic, moving randomly in the dark but upwards in the light, and tolerant of sea water but not heavy brine. Nematodes are found in the husks of planted nuts.

40—COBB, N. A., 1923. Nematodes inhabiting trees. *Journal of the Washington Academy of Sciences,* **13**, 111.

Cobb repeats his description of *Aphelenchus cocophilus* from coconut palms. (See abst. 38.)

41—COBB, N. A., 1923. The Coconut Industry, its Economic Importance, and a Serious Disease of the Coconut Caused by a Nematode. *Journal of the Washington Academy of Sciences,* **13** (9), 189.

A report of a paper presented to the Academy. The importance of coconuts was alluded to. A major disease of coconuts originally known as Root Disease and later as R.R.D. has been confirmed to be caused by a nematode, *Aphelenchus cocophilus*. The nematode was first extracted from coconuts by Mr. Nobb of the Imperial Department of Agriculture, W.I. It was later identified by Dr. N. A. Cobb who estimated that about 20,000 nematodes occurred per foot (304·8 mm) of coconut stem.

42—COPELAND, E. B., 1931. (3rd Ed.) *The Coco Nut.* Macmillan and Company Ltd., London, 233 pp.

Aphelenchus cocophilus is reported to be the causal agent of R.R.D. which is widespread in the Caribbean. R.R.D. is the same as the 'Root Disease' described by Stockdale (see abst. 274–279) and the *Diplodia* disease of Fredholm (see abst. 120). Some details of R.R.D. based on Nowell's work (see abst. 241–248) are given.

43–CORBETT, M. K., 1959. Diseases of the coconut palm. 3. Red Ring. *Principes, Florida,* **3** (1), 83–86.

Corbett summarizes the published knowledge on R.R.D. of coconut caused by *Aphelenchoides cocophilus,* which on the recommendation of Chitwood he refers to as *Chitinoaphelenchus cocophilus* (Cobb) Micoletzky. (This promotion of the subgenus *Chitinoaphelenchus* Micoletzky, 1922 to generic rank and the placing of *A. cocophilus* within it has overlooked the designation by Chitwood (see abst. 36) of *A. ormerodis* as type of *Chitinoaphelenchus*.)

44—COSTA, J. M. DA; BARRETO, A. C.; FILHO, J. C., 1973. Pragas das Palmaceas. *Ministerio da Agricultura. Instituto de Pesquisas Agronomicas Leste. Brazil Circular,* 32.

Twenty-six pests and diseases of Palms in Bahia, Brazil are described and illustrated. *Rhynchophorus palmarum, Dinamis politus, Rhinostomus barbirostris* and *Homalinotus coriaceus* are said to be the vectors of *R. cocophilus*. The nematode, disease symptoms and control methods, are described. The 5 methods of control are: cultural, drainage and plantation hygiene; eradication by burning diseased palms; soil fumigation with D–D, Nemagon, or other nematicides; trunk injection with systemic

nematicides; control of the insect vector by insecticide treatments.

45—CRANDALL, B. S.; ABREGO, L.; PATIÑO, B., 1951. A check list of the diseases of economic plants of El Salvador, Central America. *Plant Disease Reporter,* **35** (12), 545–554.

The list of nematode infections in plants in El Salvador, Central America, includes R.R.D. nematode on *Cocos nucifera.*

46—CROSSMAN, L.; CHRISTIE, J. R., 1937. Lists of plants attacked by miscellaneous plant infesting nematodes. *Plant Disease Reporter,* **21** (9), 147.

Three host plants are listed for *Aphelenchoides cocophilus* (Cobb, 1919) Goody, 1933, these are: *Cocos nucifera,* the coconut; *Elaeis guineensis,* the African oil palm; and *Phoenix dactylifera,* the date palm.

47—CUELLAR, S. R., 1960. Phytonematology in Panama and Central America. *Proceedings of the Soil and Crop Science Society of Florida, 19th Annual Meeting (1959),* pp. 430–435.

This is a report on the nematode diseases of the principal crops in Panama and Central America and on their control. R.R.D. of coconut caused by *Aphelenchoides cocophilus* is described but no adequate control measures are yet known.

48—DAO, F., OOSTENBRINK, M., 1967. [An inoculation experiment in oil palm with *Rhadinaphelenchus cocophilus* from coconut and oil palm.] *Mededelingen van de Rijksfaculteit Landbouwwetenschappen te Gent,* **32** (3/4), 540–551.

In glasshouse experiments at Wageningen, in the Netherlands, no infections of *R. cocophilus* from oil palm could be established on 125 three-month-old oil palm seedlings of different crosses, in spite of different methods of application. This agrees with observations that no natural infestation occurs before the palms are 4 years old. Successful inoculations were made with *R. cocophilus* from oil and coconut palm on 10-year-old oil palms in an apparently nematode-free plantation in the Maracay region of Venezuela. *R. cocophilus* from oil palm became established in 15 of 24 palms and from coconut in 17 of 24 palms inoculated in different ways, into the stem, in leaf axils or around the roots; all parts became infected in over 50% of cases. Two of 12 control palms appeared to be infected 8 months after the start of the experiment and one of 10 border palms outside the experimental area also showed infection. This was probably due to natural spread by means of a vector, but not *Rhynchophorus palmarum,* as this was absent in the Maracay region. One-and-a-half years after the inoculation, most of the palms in the plantation were dead or dying. This was probably due to the nematode damage, but the palms also suffered from stem sampling.

49—DEAN, C. G., VELIS, M., 1975. Differences in the effects of Red Ring Disease on Coconut Palms in Central America and the Caribbean and its control. (Abstract) *Yearly Progress Report for 1975 on Coconut Breeding, FAO Rome.*

An abstract of a paper read at the Fourth Technical Working Party on Coconut Production, Protection and Processing, Jamaica 1975, and later published (see also abst. 50).

50—DEAN, C. G., VELIS, M., 1976. Differences in the effects of red ring disease on coconut palms in Central America and the Caribbean and its control. *Oléagineux,* **31** (7), 321–326.

R.R.D. of coconut palms is a major problem in the Neotropics. In the Caribbean area, on the coconut variety 'Jamaica Tall', R.R.D. development sequence consists of: oviposition by females of *Rhynchophorus palmarum* L. infested by the nematode *R. cocophilus* in the leaf axils; weevil damage in the palm crowns; progress of a red cylinder down the stem; secondary rotting of the crown; and death of the palm 12–18 weeks after the appearance of the first clear symptoms. In El Salvador, Central America, R.R.D. in the 'Panama Tall' variety may be transmitted by 2 weevils, *Rhynchophorus palmarum* and *Rhinostomus barbirostris* F. Damage by the former and oviposition may also begin at the base of the palm and the red ring may originate at either the crown or the base; the inner margin of the ring may be diffuse or the whole centre coloured; associated crown rot is rare and palm death is often considerably delayed. The type of trap most attractive to *Rhynchophorus palmarum* (although not to *Rhinostomus barbirostris*) proved to be the Haz trap consisting of 8 pieces of R.R.D.-infected coconut stem tightly stacked together and shaded with palm leaves. In both field and laboratory tests, the attractiveness of trap wood was compared when impregnated with each of 5 insecticides. Methomyl (Lannate) was the most attractive, followed by trichlorphon (Dipterex) and pirimiphos ethyl (Primicid). Fifteen minutes exposure to the 2 former products killed the weevil within 24 hours. Carbaryl (Sevin) and carbofuran (Furadan) were repellant in action when compared against water or coconut tissue controls. All sizes of palm weevil transmit the nematode both internally and externally. A note is appended to the paper containing information on the distribution, alternative hosts, economic importance, morphology, life-cycle and control of *Rhynchophorus palmarum,* and on the damage that it causes. Trapping appears to be the only effective form of weevil control, although mildly infected palms may be saved by surgery followed by treatment of the cut surfaces with a fungicide/insecticide mixture with clay or cement.

51—DEAN, C. G., VELIS, M., 1976. Cultivo del Cocotero. [Cultivation of the coconut palm.] *Ministerio de Agricultura y Ganaderia, El Salvador,* Circular number 3, 13pp.

The growing of coconut palms in El Salvador is described. In selecting varieties for planting, Dean and Velis suggest that the Panama Tall variety is possibly more tolerant to R.R.D. and weevil attack than Jamaica Tall. Traps using 6–8 split coconut stem pieces treated with insecticide are recommended for control of the coconut weevil and thus of R.R.D.

52—DIAZ-SILVEIRA, M. F., MIJAILOVA, P. T., 1973. Los nemátodos y su relación con la 'pudrición del cogollo' del cocotero en Cuba. [The nematodes and their relationship to 'bud rot' of the coconut palm in Cuba.] *Serie Agricola, Academia de Ciencias de Cuba,* No. 29, 1–10.

The nematodes found in soil and root samples from healthy, early bud rot and severe bud rot or dead coconut palms in 18 sites in western Cuba, are tabulated. *R. cocophilus* was not found. It is concluded that none of the nematodes found was associated with bud rot.

53—DIAZ-SILVEIRA, M. F., MIJAILOVA, P. T., 1974. Los nemátodos y su relacion con la pudricion del cogollo del cocotero en Cuba. [Nematodes and their relationship to Bud Rot of the coconut palm in Cuba.] *Revista de Informacion Cientifica y Technica Cubana,* **5** (2), 10.

Essentially the same as the previous paper.

54—DUARTE, M. P., 1964. Estudio Sobre o Anel Vermelho do Coqueiro. [Study on the red ring of coconuts.] Sergipe Inspectoria de Defesa Sanitária Vegetal, Sergipe, Brazil, 235 pp.

55—DUARTE, M. P., 1964. O Anel Vermelho do Coqueiro Cruz das Almas. [The red ring in the coconut Cruz das Almas.] *Instituto de Pesquisas Agronomicas Leste, Bahia, Brazil,* Circular No. 7.

56—DUARTE, M. P., 1964. O Anel Vermelho do Coqueiro. [The red ring in coconut palm.] *La Vida Rural, Bahia,* **31** (2), 20–21.

57—DUARTE, M. P., 1968. Combate Borata do Coqueiro. [Control of the coconut palm borer.] *Mundo Agricola, Barcelona,* **10,** 28–29.

58—DUNLOP, W. R., 1922. *Report on the Economic and Natural Features of British Honduras in relation to Agriculture, with Proposals for Development.* Crown Agents for the Colonies, London, 32 pp.

Insect pests recorded include *Rhynchophorus palmarum,* L., breeding in dead and dying cohune palms (*Attalea cohune*), and also occurring in coconut palms though not as a serious pest if the palms are protected from mechanical injury and are healthy and vigorous. R.R.D. of coconuts is serious in places along the mainland coast, and particularly up the rivers. On some plantations it may cause a loss of 30% of palms as they come into bearing. Destruction of diseased palms should be enforced by law.

59—ECUADOR, 1975. El cocotero y su cultivo. [The coconut palm and its cultivation.] Boletín del Ministerio de Agricultura y Ganaderia, Ecuador. Presented as paper CNP/75/40 of the *4th FAO Technical Working Party on Coconut Production, Protection and Processing.*

R.R.D. is one of the major problems of coconut plantations on the American continent. Symptoms are briefly described. Spread of the disease is by irrigation water, insects including ants and weevils and by wind. Infected palms should be buried or their stems cut up, soaked in insecticide and used for traps for the vectors.

60—EDMUNDS, J. E., 1969. Plant nematode problems of the Windward Islands. In: Peachey, J. E. (Ed.), *Nematodes of tropical crops.* Technical Communication of the Commonwealth Bureau of Helminthology, No. 40, pp. 142–148.

R. cocophilus has reached as far north as St. Vincent in the Windward Islands where it threatens to wipe out the coconut industry in some areas.

61—EDMUNDS, J. E., 1969. Nematological research in the British West Indies. *Proceedings of the symposium on tropical nematology, University of Puerto Rico Agricultural Experimental Station,* 112–119.

R.R.D. was the second nematode disease of crops to be reported from W.I. The history of nematology in the area is discussed. After the initial work by Ashby, Nowell and Cobb in the early part of the 20th century, no further investigation of R.R.D. was carried out for 39 years until Martyn and then Fenwick undertook studies. A Red Ring Research Laboratory was set up at the Ministry of Agriculture and Dr. Fenwick became Director of Trinidad and Tobago Coconut Research Limited in 1960, where he worked with Goberdhan and Wilson. Subsequent work in Trinidad was carried out by Blair, Hagley and Griffith. Thirty-three references are made to the literature. The problem is now much better understood and a solution is closer at hand.

62—ESSER, R. P., 1969. *Rhadinaphelenchus cocophilus* a potential threat to Florida palms. *Nematology Circular, Division of Plant Industry, Florida Department of Agriculture,* Number 9, 2 pp.

All aspects of R.R.D. are briefly described. The geographical range is said to include the Belgian Congo (this report has not been substantiated). Host plants are *Phoenix canariensis, Cocos*

nucifera, Roystonea regia, Phoenix dactylifera and *Elaeis guineensis,* 'Little leaf disease' is said to be an occasional symptom in coconuts and a common one in oil palm, caused by the nematode *R. cocophilus.* The principal means of infection is by infected palm weevils carrying nematodes into leaf axils of the palm. Nematodes also enter the roots from the soil, pass from infected to healthy roots through the soil and enter leaves by passing in through the stomata. Nematodes are carried by ants and infect *Coptotermes niger* colonies. Details of infection are given. Losses are said to be heaviest in December and March (without reference to latitude) during periods of heavy rain and in poorly drained swampy areas. Zinophos at 1 : 1,000 injected into healthy palm roots protected them from the pest. Palmarol, 19·5% Endrin and Coumarone, in leaf axils reduced the disease further. Soil fumigation after burning infected palms is also recommended. R.R.D. is not present in Florida. Quarantine control is necessary to prevent its entry.

63—FAO, 1974. *Report of the 9th Session of the Plant Protection Committee for the Southeast Asia and Pacific Region, held in New Delhi, India, 2–9 November 1973.* FAO, Rome 61 pp.

An amended list is given of the destructive pests and diseases not yet established in the Southeast Asia and Pacific region (islands), this includes *R. cocophilus* on coconut palms.

64—FENWICK, D. W., 1956. Preliminary investigations into red ring disease of coconuts. *Journal of the Agricultural Society of Trinidad and Tobago,* **56**, 253–276.

Fenwick described work on *Aphelenchoides cocophilus* causing R.R.D. of coconuts in Trinidad. The importance of *Rhynchophorus palmarum* as a vector is questioned but he stressed that it was a major pest in its own right. Infection started in the base of the palm via the roots. This, together with the fact that R.R.D. seemed to be more prevalent on badly drained areas suggested that the disease was soil borne. The presence of soil nematodes in the husks of dropped seed nuts, and the finding of R.R.D. in 2 nuts, suggested that the disease could be spread to new areas by the use of infested nuts.

65—FENWICK, D. W., 1957. Red ring disease of coconuts in Trinidad and Tobago. Report No. 40617, *Colonial Office, London* 55 pp.

Fenwick describes investigations into *Aphelenchoides cocophilus* causing R.R.D. in coconuts. The very low incidence of the nematode on the coconut weevil, *Rhynchophorus palmarum,* and the difficulty in removing them shed some doubt on the importance of this insect as a vector for the disease. The distribution of R.R.D. in tissue and of weevil damage is not consistent with the former arising from the latter. An almost constant feature of R.R.D. infections is a mass of red ring tissue in the base of the palms with or without a cylinder of reddened tissue extending upwards for a varying distance. The breeding stages of the nematode are always found near the top of the cylinder. This indicates that infestation of the trunk and leaves starts at the base. The presence of nematodes in the roots of infested palms (in two cases they were found in roots of palms in which there was only very slight discolouration in the base of the trunk) and also of nematodes in the soil suggests entry via the roots. It is therefore possible that the disease is soil borne. This is supported by the fact that it appears to be more prevalent in swampy and badly drained areas. Dropped nuts suitable for planting were found to be infested with soil nematodes and in two cases *A. cocophilus* were found in the husks. This might be a factor in the spread of the disease to new areas. The disease normally affects palms less than ten years old but a few old palms were found dying from it. Symptoms in these palms were very variable and not at all typical of R.R.D. in younger palms. The nuts on these palms were not infested. The symptoms of the disease in young palms are described—it is emphasized that diagnosis based on the general appearance of palms is unreliable. The presence of the characteristic reddened ring of tissue must be established and if possible confirmed by the presence of the nematode. It is recommended that the status of the nematode in soil be investigated, as well as its incidence in dropped nuts. The absence of basic knowledge on the culture and agronomy of coconuts is a severe handicap to any programme of research into R.R.D.

66—FENWICK, D. W., 1958. Red ring of coconuts. A problem for the nematologist. *Span, London,* 2, 5–6.

After outlining the history of R.R.D. of coconuts in Trinidad, Fenwick describes the symptoms and the position in which the causal nematode, *Aphelenchoides cocophilus,* is found in the plant at different stages of the disease. Infection probably starts at the base of the palm and there are indications that the nematodes enter by way of the roots. *A. cocophilus* has been found in the soil of coconut plantations and might possibly enter the husks of fallen nuts and so be spread to new plantations. Not enough is known to recommend control measures but soil fumigation might be practicable. Further research into the biology and host-parasite relationships of the nematode is needed.

67—FENWICK, D. W., 1959. *Report on a visit to Venezuela.* Red Ring Research Scheme, Ministry of Agriculture, Central Experiment Station, Centeno, Trinidad and Tobago.

68—FENWICK, D. W., 1959. Red Ring of coconut, a problem for the nematologist. *Indian Coconut Journal,* **12** (3/4), 82–86.

This paper was previously published in *Span.* (See abst. 66).

69—FENWICK, D. W., 1959. The Nematological Aspects of Red Ring Disease of Coconuts. *Journal of the Agricultural Society of Trinidad and Tobago,* **59**, 373–395.

Fenwick's findings relating to R.R.D. are reiterated. Research confirms that there was not enough evidence to confirm root transmission. Distribution of the R.R.D. nematode in the palm was illustrated, maximum numbers occurring just below the top of the red ring; their consistent recovery from the root system was confirmed often in the absence of stem infection. Sampling techniques are compared. R.R.D. nematodes are able to survive for up to a month in soil. The future use of soil fumigants and systemic nematicides for control is considered in relation to the duration of the root phase of the disease.

70—FENWICK, D. W., 1962. The entomological aspects of red ring disease. Minutes of the Monthly General Meeting of the Agricultural Society of Trinidad and Tobago, June 14, 1962, 3–20.

The paper was later published (see abst. 72). During questions from Blair, Fenwick said that transmission by man or mechanical cultivators was a possibility.

71—FENWICK, D. W., 1962. Report on research carried out by Trinidad and Tobago Coconut Research Ltd, during 1961. *Journal of the Agricultural Society of Trinidad and Tobago,* **62** (1), 27–47.

Details of the report are given under the names of the corresponding authors. (See abst. No. 300.)

72—FENWICK, D. W., 1962. The entomological aspects of red ring disease. *Journal of the Agricultural Society of Trinidad and Tobago,* **62** (2), 265–281.

Research on the coconut palm weevil and its role as a possible vector of *R. cocophilus* is described. Nematodes were recovered, most after 24 hours, by placing a weevil and its detached wings in a small volume of aerated water in a 6 × 1 in (150 × 25 mm) tube. When fed on diseased tissue for a week, most of the weevils carried nematodes and 37% carried more than 50. When infected weevils were fed on clean palm tissue for 8 days, 17% were still infected, their nematode burden having dropped to 25% of that of weevils taken directly from infected tissue. Of 1,029 weevils collected from 5 different localities, 35% were infected. Of 405 weevils collected from 5 locations, 14% had internal infections in the gut or body cavity but experiments indicated that the nematodes could not survive for more than 5 days within the weevils. The palm weevil is considered to be an important factor in the spread of R.R.D.

73—FENWICK, D. W., 1962. Penetration of coconut tissues by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1961,* Trinidad. A1–A15.

Studies were undertaken to determine the factors governing the initial entry, the susceptibility of various tissues and the damage caused by the nematode. Penetration tests were conducted using intact surfaces, scratched and peeled surfaces of white petiole (W.P.), internodal tissue (I.T.), soft and hard stem, young and old root (O.R.) tissues. Experiments were replicated 15 times. Nematodes are capable of penetrating all types of undamaged coconut tissue. In W.P., I.T. and O.R. damage to the surface did not increase penetration: in the other three tissues it did. O.R. are probably the most susceptible tissues. Seven tables of results are included.

74—FENWICK, D. W., 1962. Palm weevil control and red ring. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad.* T1–T3.

The author briefly considers the importance of palm weevil control in R.R.D. as a result of the findings of Fenwick and Mohammed (see absts. 106, 107) and Fenwick and Maharaj (see abst. 92).

75—FENWICK, D. W., 1963. On the distribution of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960, in coconut palms suffering from red ring disease. *Journal of Helminthology,* **37** (1–2), 15–20.

The distribution of R.R.D. in 106 coconut palms is described in detail. The results indicate that infection may begin either in the crown or in the root system of the palm.

76—FENWICK, D. W., 1963. Report on research carried out by Trinidad and Tobago Coconut Research Ltd. during 1962. *Journal of the Agricultural Society of Trinidad and Tobago,* **63** (3/4), 332–345 and 495–541.

Details of the report are given under the names of the relevant authors. (See abst. No. 301.)

77—FENWICK, D. W., 1965. Root Infection Experiments. *Annual report of the Trinidad and Tobago Coconut Research Ltd. for the years 1963–1964,* 18–26.

A series of experiments on young and mature coconut palms indicated that root infections generally result in R.R.D. of the plant in young palms but, despite infection of the root system, R.R.D. often does not develop in mature palms. Resistance in the base of mature palms is suggested, to account for these observations. Nematodes move inwards from the site of root infection more rapidly than outwards.

78—FENWICK, D. W., 1966. Artificial infection studies. Root infection experiments. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–5,* 18–26.

Two weeks after roots of healthy coconut palms, of susceptible age, were exposed to R.R.D.-infested tissue, nematodes had entered the roots and moved inwards as far as the bole; outward movement was slower. After 3 or 4 weeks, exposed roots were infested for their entire length. Young roots showed similar responses to old but the spread of infestation was slower. Every root exposed became infested. Larval nematodes predominated in the roots and about 50% of the recovered nematodes were dead. Eight weeks after roots of 10 palms were exposed, neighbouring roots had not become infested but by 12 weeks infestation of the root system was general in 3 palms. At 16 weeks, generalized symptoms of R.R.D. could be detected in these palms, by which time 3 others showed root symptoms which developed for a further 4 weeks to general infestations. One further palm followed the same pattern. The last 3 palms remained disease free. Four out of 5 palms, 3 years old, developed similar symptoms in a subsequent experiment. In older palms 15–20 years of age similar trials produced generalized root infestation but no characteristic R.R.D., although the dropping of nuts and leaves characteristic of root-infested palms was apparent. In a subsequent trial using 10 susceptible palms whose root systems had been treated with Nemafos by root injection, 6 subsequently became infected with R.R.D. With a similar set of palms in which infection had been prevented by nematicide treatment none succumbed for several months after exposure.

79—FENWICK, D. W., 1967. Coconut Research in Trinidad and Tobago. *Oléagineux,* **22** (2), 87–8.

An abstract of the Annual Report of the Trinidad and Tobago Coconut Research Ltd. R.R.D. work showed that: infection can occur via the roots; coconut weevils can pupate in soil and adults emerge infected with R.R.D. nematodes; a new type of trap was developed for palm weevil; no relationship could be established between weevil populations and R.R.D. losses in plantations; insecticide screening trials continued; as did herbicide and fertilizer trials.

80—FENWICK, D. W., 1967. The Effect of Weevil Control on the Incidence of Red Ring Disease. *Journal of the Agricultural Society of Trinidad and Tobago,* **67** (2), 231–244.

Control of *Rhynchophorus palmarum*, an important vector of the R.R.D. nematode *R. cocophilus* would decrease the incidence of the disease. Experiments were conducted, using B.H.C. and Endrin, in 2 blocks of 540 palms each subdivided into a control and treatments at 1, 2 and 3 month intervals. Chemicals were applied to the leaf axils. Weevil population levels were determined at one month intervals using traps and R.R.D. palm losses were recorded weekly. Results indicate that monthly application of insecticide reduces the incidence of R.R.D. by one third; less frequent applications are ineffective. Relationship between chemically or naturally reduced weevil population level, or the fluctuation in such levels and reduction in R.R.D. loss is 'more ambiguous and uncertain'. These results suggested to the author that, in the area on which the experiment was conducted, weevils were not the only factor governing the spread of R.R.D. Large numbers of root-infected palms were later detected in the area of the experiment.

81—FENWICK, D. W., 1968. The effect of weevil control on the incidence of red ring disease. *Port-of-Spain: Agricultural Society of Trinidad and Tobago,* 15 pp.

Monthly additions of Endrin and Agrocide to the leaf axils of coconut palms were found to reduce the incidence of R.R.D. by controlling *Rhynchophorus palmarum* and so preventing the spread of *R. cocophilus*.

82—FENWICK, D. W., 1968. A note on the nematicidal properties of 'Sevin'. *Tropical Agriculture, Trinidad,* **45** (2), 125–126.

The nematicidal properties of Sevin were examined. Routine tests using the Fenwick modification of the Peters' vinegar-eelworm screening technique indicated that the chemical had an apparent LD_{50} value of about 4 p.p.m. active ingredient over a period of 24 hours. Further observations, however, showed that the nematodes were not killed outright and that their lack of negative geotropism was due to dis-coordination induced by the chemical. *R. cocophilus* was exposed to different dilutions of the chemical for 24 hours and suffered a similar dis-coordination to that of the vinegar eelworm. The LD_{50} of the chemical in these tests appeared to be in the vicinity of 20 p.p.m. but because of high mortality among the water controls during this period, accuracy of this estimate was of a very low order. Sevin dust also prevented the nematodes from penetrating coconut petiolar tissues.

83—FENWICK, D. W., 1968. Red-ring disease of the coconut palm. In: Smart, Jr., G. C. & Perry, V. G. [Eds], *Tropical nematology.* Gainesville: University of Florida Press, pp. 38–48.

Fenwick reviews the mechanism of transmission and control of R.R.D. of coconut palms caused by *R. cocophilus*.

84—FENWICK, D. W., 1969. The present outlook on red ring control. *Journal of the Agricultural Society of Trinidad and Tobago,* **69** (4), 969–979.

The 'cut and burn' policy for phytosanitation in R.R.D. of coconut is now in question due to the spreading of the disease by infected chippings. Silvisar has replaced Weedicide as a poison for infected palms due to its lower mammalian toxicity and greater ease of application. More direct control of both the nematode and its weevil vector has been achieved in experimental trials in Trinidad using Cocosev, a locally produced formulation of ground coconut shells coated with Sevin [carbaryl]. A

reasonable measure of control is reported for the first year with Cocosev being applied every 2 months to the leaf axils of susceptible palms. Clogging of leaf axils with spent chemical reduced control in subsequent years. The low mammalian toxicity of Sevin is of value. Details of methods for screening systemic nematicides are given, but the difficulties of assessing contamination of the copra hinders research in this field.

85—FENWICK, D. W., 1969. Red ring disease of the coconut palm. In: Peachey, J. E. [Ed] Nematodes of tropical crops. *Technical Communication of the Commonwealth Bureau of Helminthology,* No. 40, pp. 89–98.

The pathology, dissemination and control of R.R.D. of coconut caused by *R. cocophilus* is reviewed. Work is reported on the spread of the disease via roots, on the preference of the nematode for moist conditions and on the use of Sevin as a nematicide.

86—FENWICK, D. W., 1969. Movement of the Red Ring nematode in soil. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68, Trinidad,* 8–10.

The R.R.D. nematode favours very wet almost waterlogged soil and is probably more active in clay than in sandy soils. Nematodes were recovered at a depth of 153 mm below the surface of a column of sand extending to 254 mm above the water table when inoculated with R.R.D. infected chips on the surface. Maximum concentration of worms occurred at 76 mm. Less worms were recovered from the same depth after 14 days. Greater penetration (127 mm) occurred in sand tubes extending to 153 mm above the water table than those of 254 or 381 mm. Survival of nematodes was low, 15% survived 2 days, but they were not influenced by soil moisture content.

87—FENWICK, D. W., 1969. Screening of Chemicals for possible use in control of Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* 14–22.

As there are two methods of infection of palms with R.R.D., via the soil or via coconut weevil transmission, there must be two separate approaches to control. These are by the use of an insecticide/nematicide treatment of leaf axils and the application of a systemic nematicide to the soil. Screening of chemicals was undertaken to find suitable products which would not need to be applied more frequently than once every 3 months. Nematicidal activity and weevil kill times were defined for 11 chemicals; in addition their chemical characteristics and systemic activity were noted. Basudin, Birlane, Mocap, Nemacur, Nemafos/Zinophos, Sevin and Sumithion/Folithion have possible leaf axil application uses; Lannate and Nemacur have possible soil use and Imidan, Temik and Thimet are not suitable for use, the latter two due to their high toxicity.

88—FENWICK, D. W., 1969. Field trials with granular Sevin for the control of Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* 25–30.

Granular Sevin formulated at 5% a.i. with ground coconut shell (25–30 grit) was applied to the leaf axils of healthy young coconut palms at a dosage rate of 20 gm/leaf axil on 6 plantations. This treatment initially reduced losses due to R.R.D. which later increased to the levels of the controls at 3 of the 4 sites.

89—FENWICK, D. W., 1969. Fertilizer trials on young trees. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* 34–37.

In fertilizer trials extending over periods of up to 5 years with 4 levels of both nitrogen and potash, no effect of any treatment was observed on the incidence of R.R.D.

90—FENWICK, D. W., MAHARAJ, S., 1960. Presence of *Aphelenchoides cocophilus* in the roots of *Cocos nucifera,* the coconut palm. *Nature, London,* **185** (4708), 259–260.

Of 171 palms examined for R.R.D., 55 had root infections of which 2 had symptoms in the stem. The maximum density of worms occurred 4–8 ft (1·2–2·4 m) above the bole with infection extending up to 14 ft (4·26 m) up the palm. In the roots, nematodes were recovered to a depth of 12 in (305 mm) below the surface. Densities were less than in the stem, being 200–300 worms/gram. Wilt symptoms, but without yellowing, were seen on the leaves and fruit of root-infected palms. The root cortex of infected palms became soft, spongy and orange-red in colour. Most of the symptoms seen were not specific to nematode damage. *Rotylenchus* sp. produces similar aerial symptoms to those of *A. cocophilus* attacks. Initial infection occurs some distance from the bole. Transmission occurring through the intermingling of root systems is a possibility. Of the 55 root-infected palms, 7 developed symptoms characteristic of root infection and one of crown infection. The nematode can remain in the root system for a considerable time before infecting the stem.

91—FENWICK, D. W., MAHARAJ, S., 1962. 'In vivo' screening of nematicides using individual coconut leaves. *Annual Report of the Trinidad and Tobago Coconut Research Ltd., for the year 1961, Trinidad,* E1–E3.

Leaf perfusion tests with various dilutions of Phosdrin failed to give consistent results although some kill of nematodes, in excised pinnae, was noted.

92—FENWICK, D. W., MAHARAJ, S., 1962. Field studies on the natural spread of Red-Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* F1–F9.

A coconut plantation in Trinidad suffered a mean of 61% loss due to R.R.D., this increased to 78% nearer to swampy land. Root infections were recorded for 54 out of 184 apparently healthy standing palms, all infected palms being adjacent to infected palms. Additional root infections occurred during the experiment, further supporting the hypothesis of root transmission. Death of 2 palms was attributed to crown infection. Root infections were detected in 102 palms only 12 of which died in the 10 months of the experiment. Root infections persisted for longer than 26 months. Live *R. cocophilus* can be recovered from decaying roots up to one year after the palm is removed. In one plantation the data suggest that the palm weevil may be a vector of the nematode.

93—FENWICK, D. W., MAHARAJ, S., 1962. Water uptake of healthy and red ring infected coconut palms. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* I1–I9.

Rate of water uptake from a gravity feed can into holes bored into the stems was compared in young healthy and R.R.D. palms. Uptake was slow during the first hour but then increased rapidly. The maximum rate of uptake occurred in the first 24 hours, being 76% of total in healthy and 68% of total in diseased palms. Fluid uptake of diseased palms is lower than that of healthy palms, being 43% of uptake of healthy palms at 24 hours and 47·6% after 120 hours. Nematicides could be injected into the palm using the same apparatus.

94—FENWICK, D. W., MAHARAJ, S., 1962. The use of arsenic as an alternative to cutting and burning coconut trees infected with red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* L1–L7.

The aim of this study was to establish a technique which would rapidly kill both R.R.D. infected coconut palms and the nematodes contained within them and also make the palm unattractive to the weevil for breeding. Gravity injection of concentrated and various dilutions of Weedicide (arsenic trioxide) failed to consistently kill either nematodes or weevils in the coconut palms.

95—FENWICK, D. W., MAHARAJ, S., 1962. Field screening of nematicides for control of red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* M1–M7.

Treatment with Vapam, Phosdrin and EPN 18133 by gravity injection into R.R.D. palms, at various dilutions, failed to consistently kill nematodes or control weevil infestations in the palm. Reasons for the disappointing results are suggested.

96—FENWICK, D. W., MAHARAJ, S., 1963. Water uptake of healthy and of red ring infected coconut palms, *Tropical Agriculture, Trinidad,* **40** (2), 109–113.

Experiments using gravity injection equipment showed that coconuts with R.R.D. absorb less water than do healthy palms. Most of the water absorbed over a 5-day period by healthy and diseased palms was in the first 24 hours, the healthy palm absorbing, on average, 2·35 times as much as the diseased. The difference in uptake may be due to the partial blockage of vascular strands in infected areas or to the indirect effect of toxins lowering the efficiency of leaves in diseased palms.

97—FENWICK, D. W., MAHARAJ, S., 1963. Recovery of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 from coconut tissues. *Journal of Helminthology,* **37** (1/2), 11–14.

Several techniques were compared for the quantitative recovery of *R. cocophilus* from coconut tissue. The most successful technique consisted of chopping 15 gm of tissue for 2 minutes in a blender and allowing the suspension, in a 2 litre flask, to settle for 30 minutes. The supernatent liquid is then sieved 4 times through a 60 µm sieve. This process is 82·9% efficient and requires 75 min to complete. Approximately 100 samples can be processed in one day.

98—FENWICK, D. W., MAHARAJ, S., 1963. Observations on the course of red ring disease of coconuts caused by the nematode *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960, in naturally infected trees. *Journal of Helminthology,* **37** (1/2), 21–26.

The development of R.R.D. infections in 12 coconut palms was studied. Six coconut palms were initially infected in the base of the stem, 4 in the stem, 1 in the middle region and 2 in petioles.

99—FENWICK, D. W., MAHARAJ, S., 1963. *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 as a root parasite of coconuts. *Journal of Helminthology,* **37** (1/2), 27–38.

The results of detailed observation on the distribution of R.R.D. in coconuts is described for two distinct plantations. The methods of sampling are also described. Root infections occur frequently but do not necessarily develop into stem infections. Differences in soil conditions may account for some of the differences observed. It is suggested that two distinct phases may exist in the development of the disease. The first being the result of occasional random infection either from the soil or via a vector such as the palm weevil. The second

being the spread of infection from the roots of infected palms to the roots of healthy palms which are intermingled with the former.

100—FENWICK, D. W., MAHARAJ, S., 1966. Experiments on the control of red ring disease. Field experiments on weevil control. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1964–65,* 30–35.

This is a continuation of work previously reported using 5% B.H.C. (Agrocide 3) and 1% Endrin. Treatments were applied at intervals of 1, 2 and 3 months. One-monthly applications of B.H.C. reduced weevil populations nearly 50% against the control and the incidence of R.R.D. by 30%. The 2- and 3-monthly treatments had no significant effects. One-monthly treatments with B.H.C. appeared to prevent the upsurge of weevil populations rather than to further reduce populations which were low. No significant correlation exists between weevil population peaks and subsequent peaks of R.R.D. losses in coconut palms, which would be expected if weevils were the main factor initiating R.R.D. infections. One-monthly application of Endrin reduced the incidence of R.R.D. by 30%, but did not show any effect on weevil populations. No increase in R.R.D. followed peak populations of weevils. The authors conclude that in the plantation under study weevils are not the only factor governing the spread of R.R.D.

101—FENWICK, D. W., MAHARAJ, S., 1966. Organophosphates and red-ring control. Soil treatment with Nemafos as a protection to coconut trees. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 48.

Of 60 palms treated with 1 lb (0·45 kg) of Nemafos/palm/month in bands on the soil around the base, 7 died within the first 6 months. On the control plot 8 died. Such treatment appeared to have no effect in controlling R.R.D.

102—FENWICK, D. W., MAHARAJ, S., 1966. Organophosphates and red ring control. Soil treatment of individual roots. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 49–52.

Nematicide (Nemafos) applied directly, as a 1:70 soil mixture, along the length or at the tip of a coconut root failed to protect the root completely against invasion by R.R.D. nematodes. Invasion was reduced to 30% of the control value when the roots were challenged at the site of nematicide treatment. The degree of protection was of no practical value.

103—FENWICK, D. W., MAHARAJ, S., 1966. The effect of inorganic fertilizers on the incidence of red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 56–65.

Details are given of the results to date of a series of fertilizer trials with various stands of coconuts. A high K to N ratio (1:1) appeared to increase the susceptibility of coconut palms to R.R.D. The effect of soil potassium levels on other nematodes is discussed from the literature. It may be possible to reduce the incidence of R.R.D. very substantially by increasing the K:N ratio.

104—FENWICK, D. W., MAHARAJ, S., MOHAMMED, S., 1966. Organophosphates and red ring control. Application of Nemafos in soil. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1964–65,* 45–48.

In a standardized trial the half life of Nemafos in the soil was 4 weeks in soil at 20% moisture content and was considered to decrease exponentially. In a subsequent trial under various soil conditions and with varied rainfall the loss of chemical varied widely. Under constant rainfall conditions loss on heavy rainfall was exponential with 50% reduction every 5 days, while with lighter rainfall this loss occurred only after 10 days. Loss of chemical was directly related to rainfall. In sandy soils loss occurred more rapidly, 50% in 2 days.

105—FENWICK, D. W., MOHAMMED, M., 1962. Laboratory screening of nematicides. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* D1–D20.

The nematicidal effects of 'Weedicide', iodine, Vapam, Phosdrin, EN18133, SD1836. SD4965, Diazinon were compared in the lab by bioassay using *Turbatrix aceti,* the results are given in tables. Other work by Fenwick and Mohammed (unpublished) indicates that the response of *T. aceti* is 'not very different' from that of the red ring nematode. The organophosphates are extremely toxic to nematodes unlike some other insecticides and so are useful for the control of both the coconut weevil, vector of R.R.D., and the nematode.

106—FENWICK, D. W., MOHAMMED, S., 1962. The presence of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 on the body of the palm weevil *Rhynchophorus palmarum* (L.). *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* Q1–Q10.

Experiments were conducted in the laboratory and the field to confirm the presence of nematodes on the bodies of weevils. The percentage of nematode-positive weevils varied with location and season from less than 10% to 67%. The number of nematodes per weevil was also variable. Significant numbers of nematodes were recovered from under the elytrae of the weevils; this necessitated a special bubbler apparatus (described) for their extraction. 17% of insects kept for 8 days on nematode-free coconut retained up to 25% of the original worm

burden. There was no significant seasonal variation in worm burden on collected weevils. The results indicate that the weevil constitutes a significant factor in the transmission of R.R.D.

107—FENWICK, D. W., MOHAMMED, S., 1962. The presence of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodney, 1960 in the gut and body cavity of the adult palm weevil *Rhynchophorus palmarum* (L). *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* R1–R9.

In laboratory experiments 44% of palm weevils fed on R.R.D. tissue were infested internally, infestation reaching a maximum after 8 days. 11·2%, range 0%–17%, of field-collected weevils were infested, 6·1% with nematodes in the body cavity only, 3·75% in body cavity and intestine and 1·38% intestine infestation only. Numbers of nematodes carried per weevil varied from 0 to 135. The possibility of the weevil acting as the alternative host for the nematode is suggested.

108—FENWICK, D. W., MOHAMMED, S., 1963. Behaviour and biology of the red ring nematode. *Annual Report of the Trinidad and Tobago Coconut Research Ltd., for the year 1962,* 7–8.

R. cocophilus is inactivated at 4°–6°C. In water suspension the nematode moves up the side of a sloping dish and swims below the meniscus. This behaviour is not predictable. It is not a simple photo-or geotropism. The nematode survives for 3–8 days in tap water, survival not being influenced by aeration or the depth of the water layer. Mortality in water at 24 hours is 18·5% making it practical to use the nematode in nematicide screening trials.

109—FENWICK, D. W., MOHAMMED, S., 1963. Artificial infection studies on Red-Ring. Nut and seedling infections. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962, Trinidad,* 10–11.

Observations of the occurrence of R.R.D. nematodes in nuts and coconut seedlings, which showed no other symptoms of the disease, suggest that they may be carrying the nematodes in a latent condition. Nematodes were recovered from the husks of inoculated nuts for up to 8 weeks after inoculation and from seedlings up to 13 weeks after inoculation, including large numbers from the apple and the roots and few from the bole. These seedlings showed no apparent symptoms of R.R.D.

110—FENWICK, D. W., MOHAMMED, S., 1963. Investigations into the control of Red-Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd., for the year 1962, Trinidad,* 15–19.

Infection by *R. cocophilus* can occur via the vector palm weevil, which carries nematodes both internally and externally, or directly via the root system. Weevil attack is most common in the crown of the palm but may occur close to the base. Root infestation may persist in the root system for some time before moving into the stem. Therapeutic and prophylactic control measures are possible both in the crown and in the surrounding soil.

Application of 5% BHC. (benzene hexachloride) to the crown at various intervals did not significantly reduce crop losses or weevil populations during the first 6 months of a trial; some decrease in palm losses occurred after this time. Thirty weeks after applying Endrin (hexachlorodimethanonaphthalene) reductions in palm losses were noted in one treatment but with no reduction in palm weevil populations. All organophosphates tested 'in vitro' with the vinegar eelworm showed nematicidal effects; Phosdrin, Nemafos, Trithion, Malathion, Rogor, Ekatox and Ekatin were tested.

111—FENWICK, D. W., MOHAMMED, S., 1964. Artificial infections of seednuts and young seedlings of the coconut palm with the red ring nematode *Rhadinaphelenchus cocophilus* (Cobb). *Nematologica,* **10** (3), 459–463.

Young coconut seedlings and seed nuts were artificially infested with a suspension of about 4,000 *R. cocophilus*. In neither case did typical R.R.D. occur in the grown plants. Although nematodes colonized the tissue of young seedlings all had disappeared by 48 weeks; none of 202 plants became infested.

112—FENWICK, D. W., MOHAMMED, S., 1966. Artificial infection studies. Seed and seedling infection. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–5,* 12–14.

Some R.R.D. nematodes survived up to 16 weeks in the husks of 100 inoculated coconut seed nuts. No part of any seedlings which developed from these nuts was infested 20 weeks after inoculation.

Two plants died during the course of the experiment, one at 9 weeks which was heavily infested, and a second at 13 weeks which was nematode-free. Young seedlings inoculated close to the growing point retained nematodes in various tissues up to the 40th week. Rotting of the 'apple' was a frequent symptom in these seedlings. Those seedlings which died before the 22nd week contained nematodes; one which died at the 40th week was nematode-free.

113—FENWICK, D. W., MOHAMMED, S., 1966. Experiments on the control of red ring disease: laboratory screening tests with insecticides. Tests on insecticide formulations. Tests on the efficacy and persistency of granular insecticides. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1964–5,* 35–43.

Although field tests of monthly applications of Endrin and Agrocide reduced the incidence of

R.R.D. by 33%, treatment was not considered to be economic. A wide range of insecticides (unnamed) were compared in a preliminary screening trial. The 50 most suitable were re-screened to determine 50% response times. The notable feature of all tests was the very long reaction time to all the chemicals tested. Response time to a given pesticide sprayed onto a glass surface was shorter, often very much so, than to that sprayed onto petiolar tissue. The most promising chemicals were Thiodan, Sevin, Agrocide, Malathion, Fenitrothion and Folidol. Malathion being of short persistence was eliminated as was Folidol due to its high mammalian toxicity. At the time of the study Fenitrothion was still in the experimental stage.

The application of Endrin and Thiodan was not affected by the use of a 'sticker' (Agrotin or Tenac). Response to these insecticides was faster at higher concentrations. Preliminary trials with Sevin indicate it to have promise.

Due to the morphology of the crown of a coconut palm, the axils of leaves are subject to very strong washing action during rain. The major factor therefore in determining the suitability of an insecticide is its resistance to washing.

Granular formulations are more resistant than powders. The toxicity of granular formulations was tested giving reaction time in the following decreasing order of efficiency: 10% Nemafos; 18% Sevin; 50% BHC; 10% Fenitrothion; 10% Thimet; 10% Thiodan and 2% Endrin. 'Weathering tests' were undertaken on Thimet, Endrin, Nemafos and Thiodan. Activity of all products decreased with time; Endrin was most effective. The duration of subsequent trials with additional compounds was not sufficient to show significant results.

114—FENWICK, D. W., MOHAMMED, S., MAHARAJ, S., GOBERDHAN, L. C. 1963. Experiments in the use of organophosphates for the control of Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962*, 21–26.

Nemafos and Thimet are nematicidal and insecticidal against the coconut palm weevil. Aqueous extracts of 10% Nemafos granules produced 60% of the theoretically expected values in bioassay trials with the vinegar eelworm, Injection of different dilutions of Nemafos EC into infected coconut palms had no nematicidal effect. This lack of kill was similar to that obtained from a wide range of products which had been tested. Root injection techniques were equally disappointing. Absorption of Nemafos through the cut ends of roots provided protection of these roots when challenged with infected tissue. 73,433 nematodes entered control roots and 462 entered treated roots. No phytotoxicity was recorded at dosage rates of Nemafos up to 12 lbs/palm (approx. 5·5 kg/palm). Some treated and some untreated palms died of R.R.D. during the trials. The half life of Nemafos in the soil was 5–6 days. In soil fumigation trials on nematodes remaining in the soil or in root tissue after the removal of a dead palm, D–D proved more efficient than Nemagon.

115—FERREIRA LIMA, A. D., MARQUES DA CRUZ, H., 1945. O Anel Vermelho do Coqueiro [The Red Ring of coconut palms] *Boletim Fitosanitário, Brazil*, **2** (2), 87–114.

An illustrated account of R.R.D. is given together with detailed accounts of the biology, taxonomy and control of *Aphelenchoides cocophilus*. The origin and distribution of R.R.D. in Brazil is discussed. Other palms observed with R.R.D. include *Elaeis guineensis* and *Phoenix dactylifera*. R.R.D. is (erroneously) described as probably occurring in Cuba and the Fiji Islands. *Homalinotus coriaceus* is a probable transmitter of the nematode.

116—FERREIRA LIMA, A. D., MARQUES DA CRUZ, H., 1945. O anel vermelho grave doenca do coqueiro. [The red ring a serious disease of coconut palms.] *Divisão de Defesa Sanitária Vegetal, Rio de Janeiro, Publicação*, No. 20, 15 pp.

117—FILIPJEV, I. N., SCHUURMANS STEKHOVEN, J. H., 1941. *A manual of agricultural helminthology*. E. J. Brill, Leiden, pp. 435–438.

Taxonomic and symptomatic figures and details follow those of Cobb. Alternative hosts of the R.R.D. nematode include *Cocos nucifera, Elaeis guineensis, Phoenix dactylifera*, and the Fig tree (erroneously*). In addition to Central American and some Caribbean Islands, the disease is also said to occur in 'Oceania'. (Erroneous as R.R.D. has not been recorded outside the Neotropics.) Described amongst the symptoms are the detachment and falling off of the bark of the root and the distribution of the nematodes in the leaves.

Rhynchophorus palmarum is a transmitter of R.R.D. (but is not, as it is described, 'a termite', it is a palm weevil).

(*Probably a mistranslation of *Phoenix dactylifera*.)

118—FRANCO, E., 1953. Nota prévia sôbre as possibilidades de tratamento do 'anel vermelho do coqueiro'. [A preliminary note on the possibilities of treating 'red ring of coconut palm.'] *Revista de Agricultura, Brazil*, **28** (6), 163–174.

Franco describes preliminary experiments in which coconut palms suffering from R.R.D. caused by nematodes were injected with Rhodiatox, a thiophosphate of diethyl-p-nitrophenol. The results were inconclusive but further experiments are planned to find suitable concentrations and means of application of this chemical.

119—FRANCO, E., 1964. Estudio sobre o Anel Vermelho do Coqueiro [Study on the red ring of

coconuts.] Departamento de Defesa e inspecao agropecuária. *Ministerio de Agricultura, Brazil,* Publicação No. 6, 236 pp.

An extensive work combining original results and a review of some of the literature. A brief history of R.R.D. is given. Distribution is said to include Oceania (never subsequently confirmed). Alternative host plants are *Cocos nucifera* L., *Elaeis guineensis, Phoenix dactylifera* and *Roystonea regia.* R.R.D. is considered to have arrived in Brazil on an introduced palm, native palms are immune. Infection occurs via roots, by insect transmitters: *Rhynchophorus palmarum, Rhinostomus barbirostris* (most important in this area), *Homalinotus coriaceus* Gyll, *Dinamis politus* and *Parisoschenus obesulus* Carey, or on workers' implements. The association of R.R.D. with *Rhynchophorus palmarum* and *Phytophthora palmivora* is noted, as is an association with Bronze Leaf Wilt. *Rhinostomus barbirostris* is associated with R.R.D. and Bleeding (Stem) Disease. Symptoms of R.R.D. and morphological description of the nematode, both original and from the literature, are given with numerous photos. An unidentified fungal parasite seen on nematodes could serve as a biological control agent. Coconut palms resistant to R.R.D. occur in plantations. R.R.D. caused by *Rhadinaphelenchus (Aphelenchoides) cocophilus* can be transmitted by inoculation into the stem; symptoms develop after 60 days. Foci of infection occurred in 15 municipalities along the coastal belt of Sergipe state. Older methods of control included isolation of individuals or areas, with ditches, plantation hygiene and burning of all infected material.

New methods include trunk injection with nematicides and soil fumigation. Extensive trials were carried out on potential nematicides for trunk injection. Chemicals which showed some success in the field were: Aldrin 20 g; Aramite 20 g; Chlorocide 20 g; Ferradow 20 g; Fosferno 15 W, 100 g and 40 ml; Neantina 20 g; Semesan 30 g; Solabar 20 g.

The final recommendation was the use of Ferradow 50 g + Urea 0·5 g applied through 5 holes drilled into the palm with treatment repeated twice more within the year. 30–50% success was obtained by this method. (The economics of such treatments were not considered.)

120—FREDHOLM, A., 1909. Paper 367. Diplodia disease of the coconut palm. *Proceedings of the Agricultural Society of Trinidad and Tobago,* **9** (3), 159–172.

This paper was published at a time when the distinction between 'Bud Rot' and Root Disease (R.R.D.) was not clear. The paper describes the author's observations on a number of palms whose symptoms do not coincide with those of Root Disease (R.R.D.) He concludes that the cause of the disease is a bacterial bud rot caused by *Diplodia* sp. preceded by fungal attack. In other cases, a bacterial bud rot unassociated with fungi was seen.

121—FREMOND, Y., ZILLER, R., NUCÉ DE LAMOTHE, M., 1967. Le Cocotier. Techniques Agricoles et Productions Tropicales. [The coconut palm. Agricultural techniques and tropical production.] G–P Maisonneure et Larose, Paris, pp. 164–165.

R.R.D. is found in the West Indies and South America but not in Africa. The symptoms are briefly described and said to be similar to Bronze Leaf Wilt, the red ring is however diagnostic. No cure is known. Eggs, larvae and adults of *R. cocophilus* are found in the coloured tissues. At the first sign of attack the infested palm must be removed and burned and the soil treated with a nematicide.

122—GARCÍA DÍAZ, F., JIMÉNEZ, O. D., 1967. Informe sobre daños causados por el nemátodo *Rhadinaphelenchus cocophilus* y su vector *Rhynchophorus palmarum* en los cocoteros del litoral Pacífico Colombiano. [Report on the damage caused by the nematode *R. cocophilus* and its vector *Rhynchophorus palmarum* in coconuts of the Colombian Pacific coast.] Instituto de Fomento Algodonero, Estacion Experimental del Mira, Tumaco, 21 pp.

123—GATTONI, L. A., 1960. El Cocotero en Panama. [The Coconut palm in Panama.] Servicio Interamericano de Cooperacion Agrícola. Ministerio de Agricultura. Panama.

124—GOBERDHAN, L. C., 1962. The 'in vitro' culture of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1961, Trinidad,* B1–B7.

Attempts to culture *R. cocophilus* on maize meal agar with *Alternaria tenuis,* water agar, coconut extract-sucrose agar, sterilized coconut water, coconut tissue infusion, a modified Czapek Dox-sodium nitrate sucrose medium and aerated shallow films of tap water were unsuccessful. Survival time of nematodes in water was increased by adding sucrose or glucose. Light had no effect on growth or survival.

125—GOBERDHAN, L. C., 1962. The possible presence of a phytotoxin in Red Ring infected trees. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1961, Trinidad,* C1–C5.

The nematode *R. cocophilus,* causative agent of R.R.D., concentrates its activity in the stem where the fibrovascular bundles are densest. Death of the palm suggests a wilt disease of vascular origin, the literature relating to which is discussed. Mechanical blockage or blockage of the conducting vessels are excluded as causes of the wilt symptom of R.R.D. Other symptoms are suggestive of the presence of a

phytotoxin, 'vivotoxin'. Results of experiments confirm the presence of such a toxin produced either pathologically or as the result of the physiological breakdown of coconut tissue. This toxin produced yellowing and more rapid death of tomato seedlings.

126—GOBERDHAN, L. C., 1962. Studies on the symptomatology of red-ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* G1–G8.

An attempt was made to establish a definitive early symptomatology for R.R.D. Suspect palms were examined at weekly intervals. R.R.D. was later confirmed in 6 of the palms. The symptoms were yellowing and browning of leaves successively from the oldest. Yellowing of the leaves commenced at the tip of the leaf and progressed towards the base, while the yellowing of the pinnae commenced at either the base or the tip and at either the margin or the centre. Irregular yellowing was also noted. Rich, golden yellowing is typical in palms where infection is well advanced in the stem. It is unlikely that early infections can be detected by external symptomatology.

127—GOBERDHAN, L. C., 1962. The presence of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 in the soil. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* H1–H4.

Experiments were undertaken to determine the activity of *R. cocophilus* in soil. The nematode can move from diseased coconut tissue into moist sand but died as the sand dried out. The nematode can move vertically through moist sand at a rate of 16 inches (406 mm) in 72 hours (5·6 mm/hr), dead worms being recovered 56 inches (1420 mm) above the point of inoculation after 168 hours (8·5 mm/hr). Of 228 soil samples taken at various depths around R.R.D.-infested palms, 5 contained red ring nematodes, each of which contained one specimen only, in addition to many other soil nematodes.

128—GOBERDHAN, L. C., 1962. The use of dyes in determining the distribution of chemicals injected into coconut trees. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* J1–J5.

Preliminary results on the movement of dyes in coconut palms are reported. A 0·01% solution of Amaranth in water was gravity injected into a healthy and an R.R.D.-infected palm of about the same age. After 71 hours dye in the healthy palm was found only in the leaf base of the oldest leaf of the bud, while in the diseased palm the dye was more extensively distributed throughout the stem and all the leaf bases in the bud.

129—GOBERDHAN, L. C., 1962. Aids to the study of infection methods, Symptomatology and pathology of Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* K1–K2.

It is reported that palms have been 'boxed' in order to produce roots on the stem 2–3 feet above the ground level of other palms. Other palms are being grown under optimum conditions in sand in the laboratory, 20 of these palms being of the variety 'Malay Giant'. All these palms will be used for R.R.D. experiments.

130—GOBERDHAN, L. C., 1963. Possible presence of a phytotoxin in red-ring infected trees. *Nature, London,* **197** (4867), 619–620.

The wilt symptoms seen in R.R.D.-infected palms may be the result of the action of thermostable toxins produced in the palm as an indirect result of tissue breakdown following R.R.D. nematode invasion. Severe wilting in tomato seedlings and less severe wilting in three palm species, *Ptychorapis augusta, Licula spinosa* and *Thrinax morissii,* has been produced following their exposure to hot and cold water extracts, of products from R.R.D.-infected coconut palms.

131—GOBERDHAN, L. C., 1963. Artificial infection studies on red-ring. Stem infection experiments. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962,* 9–10.

Stem inoculation using cores of R.R.D.-infected tissue resulted in external symptoms developing 28–56 days after basal inoculation. One week after inoculation, infection was observed at the site of inoculation; after 2 weeks it had extended 2–3 in (50·8–76·2 mm) above this point and after 3 weeks, infection had spread 2 ft (609·6 mm) upwards and 6 in (152·4 mm) downwards. At this point the first external symptom, yellowing of lower leaf tips, was noted. After 4 weeks most of the stem and the lower petioles were infected. Palms inoculated at the bases of the petioles exhibited external symptoms 25–30 days later, at which time the red ring was well developed in the stem.

132—GOBERDHAN, L. C., 1963. Pathology of Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962, Trinidad,* 11–12.

A technique for fixing and embedding coconut tissue is described in which the tissue is fixed in formal-acetic acid and dehydrated 'in vacuo' in butyl alcohol. The fixed material is transferred to paraffin wax via paraffin oil-butyl alcohol and paraffin oil-wax mixtures. Nematodes are intercellular parasites in the ground parenchyma. No evidence of blockage of vascular strands was seen. The red-ring is located inside the zone of the stem where fibrovascular bundles are densest.

133—GOBERDHAN, L. C., 1963. The distribution of dyes in healthy and in Red Ring infected

trees. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962*, 20–21.

Gravity injection into a coconut palm allows a considerable quantity of chemical to be introduced into a palm. Diseased (?R.R.D.) palms absorb much less liquid than healthy palms. When the dye amaranth was added to the liquid it was shown that the liquid in diseased palms did not move into the diseased areas of the palm or move through the vascular system in such diseased areas. Dye was never seen in the red ring. Similar results were obtained using longitudinal blocks immersed in the dye. The injection of nematicides by this technique failed to kill the nematodes in the diseased tissue. This failure is explained by the lack of movement of solutions into that area. Chemotherapy would not therefore be successful in controlling R.R.D.

134—GOBERDHAN, L. C., 1964. The comparative distribution of dye in healthy and red-ring infected coconut palms. *Tropical Agriculture, Trinidad*, **41** (2), 169–174.

The distribution of dye in healthy coconut palms and in those infected with *R. cocophilus* is compared. A 1% aqueous solution of amaranth was injected into the stem of healthy and diseased palms. Selected roots of healthy and diseased palms were cut and soaked in the dye and laboratory experiments were conducted on excised leaves, roots and stems. The distribution of the dye was determined by serial sectioning the various tissues at intervals of 24, 48 and 72 hours after treatment. Experiments showed that no dye moved into the nematode-infected red ring zone of diseased palms. Because the dye failed to penetrate the infected zone, Goberdhan assumes that nematicides introduced into infected palms would similarly fail and that such chemotherapeutic measures would be impracticable.

135—GOBERDHAN, L. C., 1964. Observations on coconut palms artificially infected by the nematode *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960. *Journal of Helminthology*, **38** (1/2), 25–30.

Young palms were inoculated with *R. cocophilus*, introduced into the stem by way of an augur hole, to estimate the rate of spread of infection, the length of time from infection to appearance of symptoms and, possibly, to detect very early infection. Twenty-two palms were inoculated in their bases and 5 at the top; 10 of the former were cut and examined at weekly intervals. Fourteen to 21 days elapsed before the nematode caused appreciable damage and the first visible symptoms of the disease appeared between 21 and 28 days. Details are given of the spread of infection before symptoms were observed. It seems unlikely that very early infection can be detected easily because, whether the palms were infected at the top or at the base, infection was well advanced before symptoms were observed.

136—GOBERDHAN, L. C., 1964. The protection of coconut roots against infection by the nematode *Rhadinaphelenchus cocophilus* (Cobb). *Nematologica*, **10** (3) 353–360.

When cut roots of coconut were immersed in a solution containing 450 p.p.m. of the active ingredient of Nemafos for at least 6 days, protection against *R. cocophilus* was obtained up to 1·5 m from the treatment point. Protection persisted for up to 9 weeks.

137—GOBERDHAN, L. C., 1966. Organophosphates and red-ring control. The protection of individual coconut roots by direct injection. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for 1964–5, 43–45.*

A 1/1,000 suspension of Nemafos taken up through the cut end of a mature coconut root imparted resistance to that root when challenged with a heavy external source of red ring nematodes. This protection was observed both when the root was in contact with a supply of nematicide throughout the challenge period or only for the first 7 days of a 3-week challenge period. Protection of the root, following this treatment, lasted at least 9 weeks. Palms with untreated, challenged roots developed R.R.D. and died of the disease within 34 weeks of exposure.

138—GOBERDHAN, L. C., MOHAMMED, S., 1966. Artificial infection studies. Experiments with two-year-old plants. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–5*, 14–18.

Coconut palms growing in the laboratory were examined at various intervals following petiolar inoculation with red ring nematode. The bole still contained nematodes after 44 weeks and the roots after 86 weeks. Bole and root discolouration was not always associated with the presence of surviving nematodes. Twelve and 22 weeks after stem inoculations of similar palms a generalized discolouration of the bole was noted and nematodes were recovered from all tissues. After 44 and 68 weeks nematodes were only recovered from root samples. Root-infected seedlings from the same source showed bole discolouration and a few nematodes after 11 weeks, petiole and root infestation after 21 weeks. At 30, 41 and 52 weeks, infestations were noted in the petioles, bole and roots. Seedlings inoculated in the leaf axils contained nematodes only in the petioles after 14 weeks; at 32 weeks a palm showed symptoms of R.R.D. but nematodes were recovered only from the roots; at 45 weeks, nematodes were recovered from bole and root samples.

139—GOFFART, H., 1930. Die Aphelenchen der Kulturpflanzen (The Aphelenchs of cultivated plants). *Monographien zum Pflanzenschutz, Berlin*, pp. 70–78.

The history, biology and symptomology of R.R.D. is reported from the contemporary literature.

Morphological details are given directly from Cobb (abst. 38).

140—GONÇALVES, R. D., 1936. Doença do 'Anel Vermelho' do Coqueiro. [Red Ring Disease of the Coconut palm] *O Biologico*, **2** (1), 28–29.

In reply to a letter from Sr. Pedro Machado published December 12, 1935, the author suggests the presence of R.R.D. caused by the nematode *Aphelenchus cocophilus* from coconuts in the Barretos District, São Paulo State. A brief description of symptoms and possible control measures are given.

141.—GONÇALVES, R. D., 1937. A Doença do 'Anel Vermelho' do Coqueiro. [Red Ring Disease of the coconut palm]. *O Biologico* **3**, 102–103.

The article embodies a reply by the author to a letter dated December 10, 1935, from Dr. Bezerra Filho alluding to a disease of his coconut plantation. The author confirms from the material received and information given, the presence of an aphelenchid nematode probably *Aphelenchus cocophilus* and that the condition is very probably R.R.D. This is the first recorded case of R.R.D. from Brazil. Brief suggestions for control by phytosanitation are given.

142—GONZÁLEZ NUÑEZ, A., 1975. Fluctuación de poblaciones de *Rhynchophorus palmarum* L. en Tabasco y el grado de infestación en este insecto por el nematodo. *Rhadinaphelenchus cocophilus*. (Fluctuation of populations of *Rhynchophorus palmarum* L. in Tabasco and the level of infestation in this insect of the nematode *R. cocophilus*.) 10° Congreso Nacional Entomologico. Sociedad Mexicano de Entomologia 1975. Abstract in: *Folia Entomologica Mexicana, Tabasco, Mexico*, No. 33, 64 pp.

143—GOODEY, J. B., 1960. *Rhadinaphelenchus cocophilus* (Cobb, 1919) n. comb., the nematode associated with 'red-ring' disease of coconut. *Nematologica*, **5** (2), 98–102.

The genus *Rhadinaphelenchus* is erected for one species *R. cocophilus* Cobb, 1919 n. comb. The taxonomic history of the species is described and the species is redescribed and illustrated from specimens extracted from young coconut stem originating from Trinidad. The nematode is exceedingly long and narrow (a ≈ 100), very lithe in water and is characterized by a flap-like terminal bursa in the male and vulval flap in the female.

144—GOODEY, J. B., 1960. The classification of Aphelenchoidea Fuchs, 1937. *Nematologica*, **5** (2), 111–126.

The genus *Rhadinaphelenchus* contains one species *R. cocophilus* (Cobb, 1919) J. B. Goodey, 1960. The generic definition is given as: 'Very slender nematodes (a ≈ 100); female with vulval flap, long post-vulval uterine sac, long digitate tail; male with terminal bursal flap; apophysis present beyond spicules. Associated with Red-ring disease of coconut. The recent promotion of *Chitinoaphelenchus* to generic rank by Chitwood in Corbett (see abst. 43) to contain *Aphelenchus cocophilus* Cobb, 1919 is meaningless because it takes no account of Chitwood's action in 1935.' (see abst. 36).

145—GOODEY, J. B., 1963. *Soil and freshwater nematodes* 2nd Edition. Methuen and Co., London, pp. 146–148.

A taxonomic description of *R. cocophilus* (Cobb, 1919) Goodey, 1960 is given, using fresh material from coconut tissue originating from Dr. Fenwick in Trinidad. (The dorsal oesophageal gland is incorrectly illustrated in a ventral position.)

146—GOODEY, J. B., FRANKLIN, M. T., HOOPER, D. J., 1965. *T. Goodey's The nematode parasites of plants catalogued under their hosts*. 3rd Edition, Farnham Royal, England. Commonwealth Agricultural Bureaux, 214 pp.

Hosts of *R. cocophilus* are recorded as: *Cocos nucifera* L., *Elaeis guineensis* Jacq., *Oreodoxa regia* H. B. and K., *Phoenix dactylifera* L. and *Acrocomia intumescens* Drude.

147—GOODEY, T., 1923. A review of the plant parasitic members of the genus *Aphelenchus*. *Journal of Helminthology*, **1**, 143–156.

The six parasitic species of *Aphelenchus* are described in detail. *A. cocophilus* is redescribed from new material. Goodey felt that owing to its susceptibility to distortion on fixation there was a need for a complete redescription from fresh material which was not available to him. Symptoms of R.R.D. are given. It is suggested that the nematode may infect the plant via wounds or the stomata. Soil heat sterilization by a newly described machine may be an effective control measure.

148—GOODEY, T., 1928. The species of the genus *Aphelenchus*. *Journal of Helminthology*, **6** (3), 121–160.

The paper opens with a consideration of the taxonomic value of species host-specificity. The morphology and taxonomic positions of 7 parasitic species, including *Aphelenchus cocophilus*, and 12 free-living species is given. An alphabetical list indicating synonomy is given from which *A. cocophilus* is omitted. Details of this species in the text are given from Cobb (see abst. 38).

149—GOODEY, T., 1933. *The nematode parasites of plants catalogued under their hosts*. Imperial Bureau of Agricultural Parasitology (Helminthology), St. Albans, 80 pp.

Hosts of *Aphelenchoides cocophilus* (Cobb, 1919) Goodey, 1933, are recorded as: *Cocos nucifera* L., *Elaeis guineensis* Jacq. and *Phoenix dactylifera* L.

150—GOODEY, T., 1933. *Plant parasitic nematodes and the diseases they cause.* Methuen and Co., London, pp. 217–224.

Historical details of R.R.D. are given. The morphology of *Aphelenchoides cocophilus* is given based on Cobb's figures. The biology, life history and details of R.R.D. are given based on the contemporary literature. *Coptotermes niger, Nasutitermes ephratae* and *Rhynchophorus palmarum* are probable transmitters of the nematode. Hosts of the nematode are *Cocos nucifera, Elaeis guineensis* and *Phoenix dactylifera,* the last two species being infected in the Botanic garden, Trinidad. The Fiji islands are included, with reservation, for the geographical distribution. (The nematode has not subsequently been reported from there.)

151—GOODEY, T., 1951. *Soil and freshwater nematodes.* A monograph. Methuen and Co., London, 390 pp.

Aphelenchoides cocophilus (Cobb, 1919) Goodey, 1933 is synonymous with *Aphelenchus cocophilus* of Cobb, 1919. It is described as an obligate plant parasite.

152—GRENADA, 1920. *Report of the Agriculture Department, Grenada for 9 months, April 1–December 31, 1919,* 6–7.

Coconuts in experimental plots and in plantations in many areas of Grenada have been killed by R.R.D.

153—GRENADA, 1921. *Report of the Agriculture Department, Grenada for the year 1920. Barbados,* 9–10.

Rhynchophorus palmarum L. was observed in coconuts, dead or dying from R.R.D. and in young palms, where the hearts were often severely damaged. In all districts coconuts were infested with *Aphelenchus cocophilus.* Dead palms were destroyed as a preventive measure. Compulsory measures can be taken under the Agricultural Interests Ordinance, but have not yet been resorted to.

154—GRENADA, 1922. *Report of the Agriculture Department, Grenada for the year 1921. Barbados,* 4–5.

The insect pests recorded during 1921 include the palm weevil *Rynchophorus palmarum.* This was generally distributed throughout the island and is probably transmitting R.R.D. nematodes from dead to healthy palms.

155—GRIFFITH, R., 1967. Progress on the entomological aspects of Red Ring Disease of coconuts. I. Persisting *Rhadinaphelenchus cocophilus* (Cobb 1919) Goodey 1960 during metamorphosis of the Palm Weevil *Rhynchophorus palmarum* related to their presence on the body surface of newly emerged insects. *Journal of the Agricultural Society of Trinidad and Tobago,* **67** (2), 209–218.

Larvae, pupae and adults of the weevil were examined to determine the distribution and survival ability of nematodes in the body and during metamorphosis. Nematodes were recovered from the gut (10·6%), the haemocoel (18%) and the tracheae (67%) of larvae. During metamorphosis of naturally infested and inoculated larvae, 7% of nematodes were shed at the first (prepupal) moult, 36% at the second (adult emergence) moult and 57% (approx. 12,000 nematodes) were recovered dead or alive from the adult weevils 4 days after emergence. It is considered that the nematodes cast with the cuticles would migrate into the cocoon accounting for the observations of nematode-infested cocoons recovered from the soil by other workers and the occurrence of nematodes on the body surface of weevils pupating under otherwise nematode-free conditions. These nematodes may play a significant role in the initiation of new disease areas when the emerged insect migrates to feed.

156—GRIFFITH, R., 1968. The relationship between the red ring nematode and the palm weevil. *Journal of the Agricultural Society Trinidad and Tobago,* **68** (3), 342–356.

R.R.D. nematode larvae with pointed tails penetrated intact petiolar tissue. Round-tailed forms developed from eggs within 72 hours. R.R.D. nematodes survived in decomposing coconut stem tissue for 14 weeks at which time only pointed-tailed forms, which is the resistant and infective form, were found. At this time, the population of *Rhabditis* sp. which is also transmitted by the palm weevil began to increase. Seed transmission does not occur. Wind, water and soil transmission are of minor significance. The palm weevil carries nematodes externally and internally, but nematodes do not develop in the palm weevil (i.e. the weevil is a transmitter, not a host).

157—GRIFFITH, R., 1968. The mechanism of transmission of the red ring nematode. *Journal of the Agricultural Society of Trinidad and Tobago,* **68** (4), 437–457.

The theories of soil transmission and insect transmission of *R. cocophilus* to coconut palms are analysed, and natural evidence for the palm weevil as being a vector is discussed and summarized. Successful infections have been achieved via the crown, the base of the stem and the roots. An inoculation of at least 5,000 nematodes is required for successful infestation via leaf axils and more for entry via the roots. 200 nematodes are required if inoculated into the stem and one could establish a population, parthenogenetically, when inoculated into nuts. Natural dissemination through the soil by chippings from infected palms is, therefore,

possible. Nematodes are found both internally and externally on the adult palm weevil and internally in larvae. Only palm weevils smaller than 30 cm (presumably 30 mm!) which constitute 16% of the adult population, are responsible for transmission (a view not supported by other works (see absts. 50, 269)). These small weevils may lay unfertilized eggs at oviposition. Size differences between the sexes may limit successful copulation!

158—GRIFFITH, R., 1970. Control of red ring disease in coconut. *Crop Bulletin, Ministry of Agriculture, Trinidad and Tobago,* No. 17.

159—GRIFFITH, R., 1971. Red ring disease: the mechanism of spread and recommendations for control. *Nematropica,* **1** (1), 2 and 20.

Palm weevils, *Rhynchophorus palmarum* carrying the R.R.D. nematode *R. cocophilus* were killed by treating palms in their leaf axils with Lannate (methomyl).

160—GRIFFITH, R., 1973. Epidemiology of Red Ring Disease and control measures in Trinidad and Tobago. *In:* Griffith, R. 1973. (Ed.) *Proceedings of the 3rd Annual Symposium of Coconut Growers of Trinidad and Tobago,* 101–110.

A review of the history, development and epidemiology and spread of R.R.D. in Trinidad and Tobago and of the present situation is given from the Trinidad literature. Disease incidence varies from 4·7–60·6% on palms within plantations. The development of the epidemic of R.R.D. in Tobago following the 1962 hurricane 'Flora' is described. Palms in the 15–20 year age group acted as reservoirs for the disease. Natural cannibalism, a bacterium *Micrococcus agilis* and the development of Bud Rot in the palm, following the establishment of a weevil infestation, help to limit the weevil population levels.

161—GRIFFITH, R., 1974. Use of the frequency of occurrence of small individuals of the palm weevil *Rhynchophorus palmarum* L. in the forecasting of red ring disease outbreaks. *In:* Brathwaite, C. W. D., Phelps, R. H., Bennett, F. D. (Editors), *Proceedings of a Symposium on the protection of horticultural crops in the Caribbean held at the University of the West Indies, Trinidad,* 287–293.

A symposium version of the paper which follows. (see abst. 162).

162—GRIFFITH, R., 1974. The use of the smaller palm weevil, *Rhynchophorus palmarum* L. in the forecasting of red ring disease outbreaks. *Journal of the Agricultural Society of Trinidad and Tobago,* **74** (2), 149–158.

The frequency of occurrence of small individuals of the weevil *Rhynchophorus palmarum,* which is the main vector of red ring nematode, *R. cocophilus,* can be utilized as an index in forecasting R.R.D. outbreaks. Non-vector medium-sized palm weevils, representing the most frequent size category in the population, produce vector palm weevils, carrying nematodes in the region of the ovipositor, and non-vector palm weevils, when they are mated in diseased tissue. Larvae of vector palm weevils injected with large numbers of the nematode before pupation, were unable to remove these nematodes. In the Cedros peninsula, in Trinidad, where R.R.D. has been under control for many years, fewer vector palm weevils less than 30 mm in size are found than in heavily diseased areas. (This size specificity of the palm weevil in relation to the transmission of R.R.D. has not been confirmed in other countries.)

163—GRIFFITH, R., 1976. Some characteristics of a defence mechanism in the palm weevil *Rhynchophorus palmarum* L., against the red ring nematode, *Rhadinaphelenchus cocophilus* (Cobb) Goodey, 1960. *Journal of the Agricultural Society of Trinidad and Tobago,* 1976, **76** (3), 246–261.

Characteristics of the defence mechanism in the palm weevil against invasion by *R. cocophilus* suggest the presence of an enzyme-controlled system for the dissolution of living nematodes in the haemocoel of the larva. Only non-vector insects possess the mechanism.

164—GUYANA, 1930. Annual report for 1929 of the Ministry of Agriculture. Botanical and Mycological Division. Plant Diseases: Coconuts. *The Agricultural Journal of British Guiana,* **3** (4), 229–230.

A previous report of R.R.D. in Guyana (see abst. 175) could not be verified. Unidentified nematodes were recovered from a coconut palm and red discoloured tissue was seen in the stem but without the characteristic red ring. Surrounding palms which also succumbed to a wilt condition (? Bud Rot) did not show a red ring, and no nematodes could be recovered from them.

165—GUYANA, 1971. Guyana Ministry of Agriculture. *Annual Report for the year 1970.* Guyana: (1971?) 200 pp. Plant nematology, pp. III–8, III–18–19.

R. cocophilus is reported as being responsible for 7% of early deaths in coconut palms, in a survey carried out along the Pomeroon River, Guyana.

166—HAGLEY, E. A. C., 1960. *Report of the Entomologist.* Red Ring Research Scheme, Ministry of Agriculture, Central Experiment Station, Centeno, Trinidad and Tobago.

167—HAGLEY, E. A. C., 1962. The palm weevil, *Rhynchophorus palmarum* L., a probable vector of red ring disease of coconuts. *Nature. London,* **193**, (4814), 499

A high correlation is observed between the incidence of R.R.D. of coconut palms caused by *R. cocophilus* and palm weevil infestations. The nematode is carried externally on the weevil and internally in the digestive tract where it can survive for ten days; healthy nematodes have been obtained from weevil excrement. Adult palm weevils fed on R.R.D. tissue transmitted the disease to healthy palms.

168—HAGLEY, E. A. C., 1963. The role of the palm weevil, *Rhynchophorus palmarum,* as a vector of red ring disease of coconuts. I. Results of preliminary investigations. *Journal of Economic Entomology,* **56** (3), 375–380.

Incidence of R.R.D. is correlated with seasonal abundance of palm weevils. Weevils pick up fragments of tissue containing nematodes from diseased palms. Larval weevils are contaminated mainly from frass in tunnels, and adults are contaminated externally from bodily contact with diseased tissue and internally from feeding. Virgin insects are contaminated both internally and externally before emergence from cocoons. The number of nematodes picked up varies with the source of contamination and age and feeding history of insects. Nematodes lived 2–6 days on the body surface of insects and for up to 10 days in their body cavities. 38·5% of field-collected beetles were contaminated externally and 9·8% internally. Endrin sprayed for weevil control reduced the incidence of R.R.D.

169—HAGLEY, E. A. C., 1963. The role of insects as vectors of red ring disease. *Journal of the Agricultural Society of Trinidad and Tobago,* **63** (3), 271–283.

Hagley records the recovery of *R. cocophilus* from a few individuals of *Metamasius hemipterus, Rhina barbirostris, Hemiphileuros* sp. and *Hololepta* sp. (all Coleoptera) but concludes that their significance as vectors of the disease is negligible when compared with the role of *Rhynchophorus palmarum.* The paper also reviews some of Hagley's earlier work.

170—HAGLEY, E. A. C., 1963. The role of insects as vectors of Red Ring Disease. *Journal of the Agricultural Society of Trinidad and Tobago,* **63**, 396–404.

The paper considers insect vectors of R.R.D. in Trinidad. Of 57 species associated with coconuts only *Rhynchophorus palmarum* is important as a vector. *Aspidiotus destructor* is a major problem of palms in its own right. Weevils become contaminated both internally and externally when they visit infected coconuts; this was confirmed in laboratory experiments, information being given on worm burdens. 38·5% of weevils examined were contaminated externally. Nematodes were adversely affected on passage through the insect gut. Highest incidence of R.R.D. levels were recorded at the end of the wet season and beginning of the dry, this corresponded with the peak population of the weevil. Weevil control could result in a 30% reduction of R.R.D. losses. A spray programme with 1/25–1/30 v/v Endrin was recommended.

171—HAGLEY, E. A. C., 1964. Role of insects as vectors of red ring disease. *Nature. London,* **204** (4961), 905–906.

R. cocophilus was recovered from the body surface of 4 of 11 species of beetles, and from none of 5 hymenopteran and one isopteran species collected from palms infected with R.R.D. Eight *Metamasius hemipterus* carried live nematodes, and 5 dead nematodes. Six *Hololepta* sp., one *Hemiphileurus* sp., and one *Rhina barbirostris* carried dead nematodes. These beetles play a minor role as vectors of R.R.D.

172—HAGLEY, E. A. C., 1965. On the life history and habits of the palm weevil *Rhynchophorus palmarum. Annals of the Entomological Society of America,* **58** (1), 22–28.

Precise details and timing of each stage of the life cycle of the palm weevil are given. Palm weevil infestation of palms was usually associated with R.R.D. Numerous alternative palm hosts of the weevil exist, as well as root and fruit crops.

173—HAGLEY, E. A. C., 1965. The mechanism of transmission of *Rhadinaphelenchus cocophilus* by the palm weevil, *Rhynchophorus palmarum. Phytopathology,* **55** (1), 117–118.

R. cocophilus were found in the first excrement of virgin adult *Rhynchophorus palmarum* given their first meal on soft stem tissue in which the nematodes were active, but not when fed on hard fibrous tissue or on soft tissue where the nematodes were inactive and moribund. In laboratory tests, few nematodes were transmitted from diseased to healthy tissue on the proboscides of the adult weevils during feeding.

174—HAGLEY, E. A. C., 1967. A small cage for the collection of insect excreta. *Journal of Economic Entomology,* **55** (2), 261.

A simple cage system is described by means of which excreta of the coconut weevil may be collected for the detection in it of viable specimens of *R. cocophilus*, the causative agent of R.R.D.

175—HARRISON, J. B., STOCKDALE, F. A., 1912. The cultivation of coconuts in British Guiana. *Journal of the Board of Agriculture of British Guiana,* **5**, 200–211.

Root Disease (R.R.D.) occurs on heavier land in British Guiana (Guyana). Aerial symptoms may be confused with Bud Rot but the red discolouration of the stem and the rotting of the roots are characteristic. Control is by removal and destruction of all infected material. Replanting should not take place for some time. Drainage of the soil should also receive attention. (This is the earliest

definitive report of R.R.D. from mainland South America, the validity of which was later questioned (see abst. 164, 183).)

176—HART, J. H., 1905. Coco-nut Disease. *Bulletin of Miscellaneous Information, Royal Botanic Gardens, Trinidad,* **6**, 241–242.

The author reports a visit to the west coast of Trinidad to examine a new disease of coconuts (R.R.D.) Fungi and bacteria were recovered from diseased leaves. It was recommended that a mycologist should examine the situation. (This is the first published note on R.R.D.)

177—HART, J. H., 1905. Bud Rot Disease of coconuts, Gulf Coast 1905. Preliminary report by Mr J. H. Hart. Paper read to the Agricultural Society of Trinidad and Tobago, September 12 1905. *Bulletin of Miscellaneous Information, Royal Botanic Gardens, Trinidad,* **6**, 242–243.

Accompanied by a Mr. Greig, Hart visited La Retraite Estate, Cedras, Trinidad, to investigate a coconut disease. From the condition of the plantation the disease had 'been present in more or less severity for years'. Bacteria were noted on examination of the stems and a red ring was seen in the stems, the discolouration extending up to and into the leaf bases. Rotting of the crown was also evident (Bud Rot). The condition is said to be similar to Coconut Fever (probably Lethal Yellowing) reported in 1893. No correlation was seen between the disease and the presence of palm weevils. (This is the first specific technical reference to R.R.D.)

178—HOOF, H. A. van, SEINHORST, J. W., 1962. *Rhadinaphelenchus cocophilus* associated with little leaf of coconut and oil palm. *Tijdschrift over Plantenziekten,* **68** (5), 251–256.

Van Hoof & Seinhorst review the literature on 'little leaf' disease of coconut and oil palm. In Surinam the deformed little leaves of both plants have suberized patches on the inner side of the main vein of the leaf stalk correlated with *R. cocophilus* feeding ectoparasitically on the young leaves folded in the bud. A correlation with R.R.D. of coconut might be expected but was not found. Inoculation of oil palms with *R. cocophilus* in the rainy season caused 'little leaf' disease in one case out of 5. The disease also occurred in Guyana.

179—HOYLE, J. C., 1968. A simple method for poisoning coconut trees. *Journal of the Agricultural Society of Trinidad and Tobago,* **68** (4), 459–465.

Ten chemicals were tested to ascertain their effectiveness in killing coconut palms infected with *R. cocophilus*. Seven had no effect on the palm since the disease limits the movement of fluids in the stem. Of the remaining 3 chemicals, Konesta (TCA) killed palms within 8 weeks, Daconate (MSMA) killed them within 4 weeks and Silvisar (cacodylic acid) killed them within 2 weeks. Both Daconate and Silvisar prevented the breeding of weevils in poisoned palms but neither had any effect on the nematode population. Silvisar is recommended and the technique for poisoning coconut palms is described.

180—HOYLE, J. C., 1969. Phytosanitation. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* 12–14.

Nine herbicides were compared for their effectiveness in killing R.R.D.-infected palms and in preventing these palms acting as reservoirs for the palm weevil. 2,4–D; 2,4,5–T; 2,4–D + 2,4,5–T; Bromacil and Picloram had little effect. TCA killed the palms over an 8 week period which was considered to be too long. Both MSMA and cacodylic acid successfully killed the palms in an acceptable time, the former was considered to be expensive: 5 ml of the latter with an equal quantity of water injected into a palm through a hole bored into the stem killed palms up to 7 years of age. Double dosages were required on older palms. The LD50 of cacodylic acid is much lower than that of arsenic trioxide which had been previously recommended.

181—HOYLE, J. C., 1969. Investigations into the use of systemic insecticide/nematicides for red ring control. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* 24–25.

In bioassay tests using *Turbatrix aceti* a 5% solution of Nemacur P sprayed around the base of a palm and leaf petioles was taken up by the palm and 10% Nemacur granules or 2·5% Nemacur paste applied to leaf axils was taken up in very small quantities. The chemical was first detected in the leaves 2 weeks after application and persisted until week 8.

182—HOYLE, J. C., 1971. Preliminary investigations into the use of systemics for control of red ring disease of coconuts. *Experimental Agriculture, Trinidad,* **7** (1), 1–8.

In tests for control of R.R.D. of young coconut palms, caused by the nematode *R. cocophilus* in Trinidad, 3 methods of applying nematicides were used. Bidrin (dimethyl 2-dimethylcarbamoyl-1-methylvinyl phosphate) and Nemacur were injected into the stem of the coconut palm at 2·4 and 2·0 g. per palm, respectively. Lannate (methomyl) at 5 g. per palm, Nemacur at 10 g. per palm and Temik (aldicarb) at 10 and 5 g. per palm were applied to the leaf axils and Lannate, Nemacur and Temik all at 10 g. per palm were applied directly to the soil. Stem injection was found to be impractical due to the rapid breakdown of the chemicals and the damage to the palms. Of the 3 compounds applied to leaf axils, only Temik was absorbed in significant amounts. All compounds applied to the soil were well absorbed by the roots and leaf extracts were lethal to a high percentage of *Turbatrix aceti* in *in vitro* tests. Lannate broke down too quickly to be of practical use.

183—HUGGINS, H. D., 1930. Coconut cultivation in British Guiana. *The Agricultural Journal of British Guiana*, **3**, 164–175

R.R.D. has only been reported once from Guyana (see absts. 164, 175). Huggins questions the validity of that report. R.R.D. is not a factor affecting coconuts in Guyana.

184—HUSAIN, S. I., KHAN, A. M., 1967. On the status of the genera of the superfamily Aphelenchoidea (Fuchs, 1937) Thorne, 1949 with the descriptions of six new species of nematodes from India. *Proceeding of the Helminthological Society of Washington*, **34** (2), 167–174.

Six new species of the family Aphelenchoididae are described and illustrated from Uttar Pradesh, India. Two new subfamilies, Seinurinae n. subf. and Rhadinaphelenchinae n. subf., are proposed and a key to the subfamilies of the Aphelenchoididae is presented.

185—IMPERIAL DEPARTMENT OF AGRICULTURE FOR THE WEST INDIES, 1911. Coco-nut cultivation in the West Indies. *Pamphlet Series*, Number 70, 41 pp.

Root Disease (R.R.D.) listed as a fungus disease affects palms which have commenced to bear fruit. Symptoms are described. Aerial symptoms resemble those of Bud Rot but the destruction of the outer tissue of roots and the red ring, extending only 2–3 feet up the stem, are diagnostic. An alternative to a distinct red ring, the discolouration of the tissues near the centre of the stem, is described. For control, infected palms with their root systems should be dug up and destroyed and the land fallowed for 1 year. Attention should be paid to cultivation and drainage on infected land.

186—JACKSON, T. P., 1926. Work connected with insect and fungus pests and their control. *Report of the Agriculture Department St. Vincent for the year 1925*, pp. 13–20.

R.R.D. of coconuts, caused by the nematode, *Aphelenchus cocophilus*, Cobb, has made no progress, probably owing to the fact that the last two years have been exceptionally dry.

187—JAMAICA COCONUT INDUSTRY BOARD, 1966. *6th Report of the Research Department for the period June 1965–June 1966*, Jamaica. p. 20.

A field trial in Colombia at the Arocataca Field Station of the Cotton Development Institute tested the susceptibility of coconut varieties to R.R.D. The varieties Solomon Island Tall, F.M.S. (Malayan Tall), Rennell Island Tall, Ceylon Tall and local Colombian selections (presumably Jamaican Tall) were planted (see also abst. 188).

188—JAMAICA COCONUT INDUSTRY BOARD, 1971. *Eleventh Report of the Research Department for the period July 1970 to June 1971*, Jamaica, 90 pp.

The results of the trial on the susceptibility (see abst. 187) of coconut varieties to R.R.D. nematodes indicated no resistance in any varieties tested. All varieties showed symptoms of R.R.D. following inoculation.

189—JOFFILY, J. M., 1948. A doença do anel vermelho do coqueiro e su ocorrencia no Brasil. [The red ring disease of coconuts and its occurrence in Brazil.] Servicio Nacional de Pesquisas Agronomicas, Rio de Janeiro, Brazil. *Boletim*, **3**, 64 pp.

Joffily gives a full account of the history, occurrence, geographical distribution, economic importance, symptoms and aetiology of R.R.D. *Aphelenchoides cocophilus*, the causal nematode, is described from the literature. Recommended control measures include phytosanitary measures, the immediate destruction of diseased plants with disinfection of the surrounding soil, and the control of insects visiting the coconut palms which might spread the nematode. Coconut palms were introduced into Brazil and cultivated along the Atlantic coast 400 years ago. They were introduced from Asia or Polynesia. (No evidence for this theory as to the origin of the coconut palm is given.)

190—JOHNSTON, J. R., 1910. The serious coconut palm diseases in Trinidad. *Bulletin, Department of Agriculture, Trinidad*, **9**, 25–29.

In a paper critical of Hart (see absts 176, 177), Stockdale (see absts 274–279), Barrett (see abst. 10) and Fredholm (see abst. 120), Johnston considers 'Bud rot' to be a single disease. The 'incomplete' observations of the above authors are compared and the conclusion is drawn that the variously described conditions such as Fungal Bud Rot, Bacterial Bud Rot and Root Disease (R.R.D.) are all aspects of the same condition. The red ring symptom of Root Disease (R.R.D.) is not considered further. With an absence of original research of his own, the author is unable to suggest the cause of 'Bud Rot', but agrees that it may be caused by bacteria and/or fungi as suggested, after several years of study on the condition, by the above authors.

191—JOHNSTON, J. R., 1912. The History and Cause of the Coconut Bud-Rot. *Bulletin No. 228, U.S.D.A. Bureau of Plant Industry*, 175 pp.

Johnston disagrees with the findings of Stockdale (see absts 274–279) and Barrett (see abst. 10) who found that the majority of palms were dying from 'Root-disease' (R.R.D.); he states that '. . . this is contrary to the observations of the writer . . . the disease called the "root disease" (R.R.D.) is very little understood and has no proven cause.'

192—JOHNSTON, J. R., 1920. Review on: The red ring or 'root' disease of coconut palms by William Nowell. *Phytopathology*, **10**, 401.

Johnston reviews Nowell's paper (see abst. 242). Johnston notes that, based on his own observations, R.R.D. also occurs in Cuba and Panama. (The observation of R.R.D. in Cuba has never been confirmed subsequently. Johnston considered R.R.D. to be the same disease as Bud Rot.)

193—KOSHY, P. K., SOSAMMA, V. K., PREMACHANDRAN, D., 1977. Nematodes associated with coconut. *Indian Coconut Journal*, **8** (3), 1–2.

R. cocophilus is included in the list.

194—KRAAIJENGA, D. A., HOOF, H. A. van, 1962. *Cocos Nucifera* L. Opmerkingen over de cultuur van de kokospalm naar aanleiding van een studiereis naar Brits Guyana in december 1961. [Observations on the cultivation of coconut palms from studies in British Guiana in 1961.] *Verslagen en rapporten van het Department van Landbouw en Visserij in Suriname*, Number 58, 16 pp.

195—KRAAIJENGA, D. A., OUDEN, H. den, 1966. 'Red Ring' Disease in Surinam. *Tijdschrift over Plantenziekten*, **72** (1), 20–27.

In Surinam, R.R.D. in coconut caused by *R. cocophilus* could not be found under natural conditions although 'little leaf' symptoms indicated the presence of the nematode. The weevil vector *Rhynchophorus palmarum* was collected from coconut and oil palm plantations and was contaminated with the nematode. R.R.D. symptoms were induced in coconut by sealing 'little leaf' leaves into holes drilled in the bole and in oil palm by removing dead leaf axils and cortex, giving access to the vector, but they developed slowly. *R. cocophilus* is sensitive to drought and it is suggested that dry periods twice a year prevent the effective contamination of the vector.

196—LEVER, R. J. A. W., 1969. Pests of the coconut palm. *F.A.O. Agricultural Studies*, No. 77, F.A.O. Rome. 143–144.

R. cocophilus Cobb causes the fatal R.R.D. of coconuts. It is transmitted by the palm weevil *Rhynchophorus palmarum* and is worst in neglected plantations due to the availability of breeding sites for the weevil. Symptoms include the presence of a red band in the stem, which is said to start about 1–2 metres above ground level, red streaks in the leaf petiole and dry flaky discoloured roots. There is always yellowing and browning of the leaves starting from the tips followed by shedding of the leaves and nuts and secondary bacterial bud rot. The presence of a thermostable toxin associated with the nematode is the cause of tissue decomposition. 9·8% of weevils in Trinidad are said to be infested with the nematode from tissue fragments or weevil excreta. About 66,000 nematodes occur per metre of stem. Other palms infested include *Roystonea* sp., *Elaeis* sp. and *Phoenix* sp. Control may be effected using 19·5% Endrin with coumarone. Dieldrin and Parathion are less effective. D–D applied to the soil and 0.1% Nemafos injected into the roots are also suggested.

197—LICERAS ZÁRATE, L., 1967. El Nematodo: *Rhadinaphelenchus cocophilus* (Cobb, 1919) J. B. Goodey, 1960, agente causal de la enfermedad del Anillo Rojo del Cocotero, recientemente detectado en Tumbes. [The Nematode: *R. cocophilus* (Cobb, 1919) J. B. Goodey, 1960, causative agent of the Red Ring Disease of Coconuts, recently Detected in Tumbes.] *Revista Peruana de Entomologia*, **8** (1), 68–73.

The first record of *R. cocophilus* in Peru. R.R.D. is found in coconuts associated with the fungus *Thielaviopsis paradoxa* which was said to be responsible for the red colouration of the trunk; it is probably transmitted by the coconut weevil *Rhynchophorus palmarum*. In the introduction R.R.D. is (erroneously) reported from India.

198—LICERAS ZÁRATE, L., 1967. El nematodo: *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960, agente causal de la enfermedad del Anillo Rojo del cocotero recientemente detectado en Tumbes. [The nematode: *R. cocophilus* (Cobb, 1919) Goodey, 1960 the causative agent of R.R.D. of the coconut palm recently found in Tumbes.] *Agricultura y Ganadería Tropical, Perú*, **1** (2), 27–29.

199—LORDELLO, L. G. E., 1953. Contribuição ao conhecimento dos nematódeos do solo de algumas regiões do Estado de São Paulo. [*Contribution to the understanding of the soil nematodes of various regions of the State of São Paulo*]. Thesis, Escola Superior de Agricultura 'Luiz de Queiroz' da Universidade de São Paulo, Brasil, 80 pp. English summary pp. 63–66.

The distribution of the 50 genera of nematodes recorded for São Paulo is listed. This includes *Aphelenchus cocophilus* on coconuts.

200—LORDELLO, L. G. E., ZAMITH, A. P. L., 1954. Constataçao da moléstia do 'anel vermelho' do coqueiro no Estado do Rio de Janeiro. Redescrição do agente causador—*Aphelenchoides cocophilus* (Cobb, 1919) Goodey, 1933 (Nematoda, Aphelenchoidea). [Reported disease of 'Red Ring' of coconut palm in the State of Rio de Janeiro. Redescription of the causal agent *A. cocophilus* (Cobb, 1919) Goodey, 1933 (Nematoda, Aphelenchoidea)]. *Anais da Escola Agricultura Luiz de Queiroz, Universidad de Sao Paulo, Brasil*, **11**, 125–132.

Aphelenchoides cocophilus which is associated with red ring disease in the coconut palm *Cocos nucifera*

is redescribed. This is the first time it has been found in the State of Rio de Janeiro. The males had shorter and the females longer tails than the 50μ and 80μ recorded, respectively, by Cobb for worms 1,000μ long. In the present material males 824·7–1,421·4μ in length had tails measuring 30·6–36·17μ, while the females, 830·8–1,113·8μ long, had tails of 85·7–104μ.

201—LUC, M., HOESTRA, M., 1960. Les nématodes phytoparasites des solo de cocoteraie du Togo. [The phytoparasitic soil nematodes of coconut palms in Togo.] *L'Agronomie Tropicale,* **15** (5), 497–512.

R. cocophilus was not found among the many nematodes recovered from 140 soil samples from coconut palm groves in Togo suffering from 'St. Paul Wilt' (Kaincope Disease) nor were nematodes implicated in that disease.

202—MAAS, P. W. Th., 1969. Two important cases of nematode infestation in Surinam. In: Peachey, J. E. (Ed.) *Nematodes of tropical crops.* Technical Communication of the Commonwealth Bureau of Helminthology, Number 40, pp. 149–154.

Coconut and oil palms with little leaf and R.R.D. were studied. *R. cocophilus* was inoculated into oil palms and the seasonal degree of contamination of *Rhynchophorus palmarum* with the nematode was evaluated.

203—MAAS, P. W. Th., 1970. Contamination of the palm weevil (*Rhynchophorus palmarum*) with the red ring nematode (*Rhadinaphelenchus cocophilus*) in Surinam. *Nematologica,* **16** (3), 429–433.

Five specimens of healthy 4 to 7-year-old coconut, oil palm, and the wild palms *Mauritia flexuosa* and *Maximiliana maripa* were inoculated with *R. cocophilus.* Five months after inoculation, 2 oil palms and 2 coconut palms had died from R.R.D. and nematodes were abundant in the red discoloured stem tissue. One year after inoculation, the remaining palms were felled. Three showed symptoms of little leaf and *R. cocophilus* was found on the deformed leaves. Contaminated palm weevil larvae were found in the crowns of several palms. It was found that the red ring nematode and its vector, the palm weevil, could breed in newly felled trunks of cultivated and wild palms.

204—MAAS, P. W. Th., 1970. Contamination of the Palm Weevil (*Rhynchophorus palmarum*) with the Red Ring Nematode (*Rhadinaphelenchus cocophilus*) in Surinam. *Oléagineux,* **25** (12), 653–655.

R. cocophilus is known to occur in oil palms and coconuts in Surinam but R.R.D. symptoms have not been reported. Coconut, oil and two wild palms, *Mauritia flexuosa* L. and *Maximiliana maripa* Drude, were inoculated with R.R.D. tissue. Of 5 R.R.D.-free palms of each species inoculated, 2 coconut palms, 2 oil palms, one *Mauritia flexuosa* and one *Maximiliana maripa* supported the nematode population for one year and developed various symptoms. The remaining palms showed discolouration of the stem for 50 cm around the site of inoculation; nematodes could not be recovered. Two of each species of palm were felled in the field and examined at various intervals, nematodes and weevils containing nematodes were recovered from each species. The absence of the disease at a plantation level cannot be explained. The frequency of cut stems in the jungle used by natives for breeding palm weevil larvae for food could account for the high incidence of weevils carrying nematodes.

205—MAAS, P. W. Th., WOUDENBERG, J. R., IMAMBAKS, M. J., 1968. Roderingziekte van kokos en oliepalm. [Red Ring Disease in coconuts and oil palm.] *Jaarverslag 1967. Landbouwproefstation.* [*Annual report for the year 1967 of the Agricultural Experimental Station],* Surinam, pp. 11.

R.R.D. caused by *R. cocophilus* is reported from Surinam in coconut and oil palm associated with 'Little leaf'. The frequency of occurrence of *Rhynchophorus palmarum* infested with the nematode is recorded from various regions.

206—MACHADO, A. A., 1946. O anel vermelho do coqueiro. [The red ring disease of coconut palms]. *Agricultura e Pecuaria, Rio de Janeiro,* **17** (281), 32–33

207—MACHADO, A. A., 1947. Sobre a ocorrencia do anel vermelho no Estado do Paraiba. [On the occurrence of red ring in the State of Paraiba.] *Boletim da Secretaria da Agricultura, Industria e Comercio. Pernambuco,* **14** (1), 140–143.

The presence of the R.R.D. nematode *Aphelenchoides cocophilus* is confirmed on coconut palms in the state of Paraiba, Brazil. *Phoenix dactylifera* and *Eleais guineensis* are alternative hosts. Other fungal and insect pests of coconuts also occur.

208—MAHARAJ, S., 1962. Field population studies on the palm weevil *Rhynchophorus palmarum* (L). *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* P1–P11.

Simple split log traps were used to determine fluctuations in the population levels of palm weevils throughout the year. A correlation was obtained at one site, which from preliminary data was not repeated at other sites, between peak population levels and rainfall of the previous month. Traps prepared from R.R.D. palms were less attractive than those prepared from healthy palm stems.

209—MAHARAJ, S., 1963. Field observations on red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962, Trinidad,* 12–13.

Further observations were made on coconut palms in a young plantation (see abst. 92). Ten palms which had shown root infections of R.R.D. the previous year now exhibited no symptoms while 2 others were still infected. Thus root infections had not spread up into the bole in over 12 months. These palms were 10 years old. Rapid invasion of the stem following root inoculation has been reported in younger palms.

210—MAHARAJ, S., 1963. Molasses as an attractant for the palm weevil. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962, Trinidad,* 14–15.

Preliminary results of the use of molasses as an attractant for the palm weevil are not encouraging but the idea warrants further study as a means of controlling the palm weevil, which transmits R.R.D.

211—MAHARAJ, S., 1964. The use of arsenic on Coconut Trees suffering from Red Ring Disease. *Journal of the Agricultural Society of Trinidad and Tobago,* **64** (1), 59–66.

The use of arsenical solutions for killing R.R.D.-infested coconut palms is examined. A 1/10 solution of Weedicide, 1 lb of arsenic trioxide/gallon (100 g/l) killed the palms and controlled weevils in them. The chemical had no effect on the nematode population. Application of the solution was by gravity injection; palms differed greatly in the amount of liquid taken up in 24 hours. This control method for R.R.D. or weevil control is not as effective as 'cutting and burning'.

212—MAHARAJ, S., 1964. The development of the Palm Weevil in felled Coconut Trees. *Journal of the Agricultural Society of Trinidad and Tobago,* **64** (1), 67–74.

A series of experiments showed that adult weevils emerge from R.R.D.-infected palm trunks after they have been cut down. Nematode-positive adult weevils also emerged from cocoons, composed of grass root fibres, recovered from soil below cut stems.

213—MAHARAJ, S., 1965. A new design of trap for collecting the Palm Weevil *Rhynchophorus palmarum* (L). *Tropical Agriculture, Trinidad,* **42** (4), 373–375.

A trap is described for collecting palm weevils from plantations. R.R.D. coconut tissue is less attractive than healthy tissue. There is a danger with all traps using R.R.D. tissue of aiding the spread of the nematode by contaminating weevils which visit the trap. This can be partially prevented by dusting with 5% BHC. The traps were more effective and cheaper to use than split log traps.

214—MAHARAJ, S., 1966. Organophosphates and red ring control. Soil application of Nemafos in relation to root infection. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 48–49.

Soil applications of 3 lbs (1·36 Kg) of Nemafos/palm/month did not impart any resistance to attack by the R.R.D. nematode when roots were heavily challenged one week after the second application of nematicide. Nematodes were recovered from all roots two weeks after exposure.

215—MAHARAJ, S., 1966. Use of arsenic on coconut trees suffering from red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 52–54.

Cutting and burning of R.R.D. infected palms has been the only method of killing the nematodes contained within them. The treatment of R.R.D. coconut palms by gravity injection, with 5% and 10% solutions of Weedicide reduced the number of palms harbouring weevils to 6/30 and 4/30 respectively. At 2·5% solution, the treated palms were more heavily infested than the controls (no figures given). This treatment therefore limits the spread of R.R.D. by preventing the development of the weevil vectors infested with R.R.D. nematodes. Less successful treatments at 5% and 10% were associated with a low uptake of the herbicide. It was recommended that palms be treated as soon as possible after symptoms develop.

216—MAHARAJ, S., 1966. Spread of infection when cutting and burning trees infected with Red Ring Disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1964–65,* 55–56.

Neighbouring palms to those R.R.D.-infected palms treated by cutting and burning often develop the disease. From a series of experiments using chips from infected palms, there is very strong evidence to suggest that such chips from infected palms cut down with axes are the source of the spread of the disease. New recommendations for coconut plantation phytosanitation will be made.

217—MAHARAJ, S., 1968. The spread of red ring disease of coconuts from chips of infected tissue dropped on the ground. *Journal of the Agricultural Society of Trinidad and Tobago,* **68** (3), 333–338.

Wood chippings from coconut palms infected with *R. cocophilus* were shown to spread red ring disease. Chippings placed on clay gave better transmission of the disease than chippings placed on sand.

218—MAHARAJ, S., 1969. The spread of Red Ring Disease of coconut by chips of infected tissue dropped on the ground. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68,* Trinidad, 10–11.

Palms exposed to chips of R.R.D.-infected coconut tissue, simulating those produced by chopping with an axe, became infected with R.R.D. Of 105 palms on clay soil, 50 became infected after such treatment against 7 control palms. On sandy soil, 12 treated and 1 control palm became infected. Losses on clay soil were greater when the palms were challenged during wet weather. This was due to the greater water-holding capacity of the clay. The original cut and burn recommendation to farmers was modified to poisoning of the palms.

219—MAHARAJ, S., 1969. Distribution of infection in roots of trees in the early stages of red ring disease. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the years 1966–68*, 23–24.

Evidence exists that R.R.D. can be transmitted from diseased to healthy palms through their respective root systems. This transmission depends upon the extent of intermingling of the two root systems and the extent of spread of the disease in the roots of infected palms. Of 46 roots from 8 infected palms examined along their length (average length 12 ft (3·66 m)), 38 were infected as far out as the root tips. In 6 of the palms the roots intermingled with those of adjacent palms.

220—MAI, W. F., LYON, H. H., 1962. *Pictorial key to genera of plant parasitic nematodes.* Department of Plant Pathology, Cornell University, N.Y. pp. 8–8b.

A brief description of *R. cocophilus* is given based on Goodey (abst. 143). The symptoms of R.R.D. in coconut palms include death of the leaves, the growing point, the flowers and eventually the entire palm. The diagnostic features of the genus based on the description by Thorne (abst. 291) are given.

221—MALAGUTI, G., 1953. 'Pudricion del Cogollo' de la Palmera de Aceite Africana (*Elaeis guineensis* Jacq.) en Venezuela. (Bud Rot of the African Oil Palm (*E. guineensis* Jacq.) in Venezuela) *Agronomia Tropical*, **3** (1), 13–31.

Three types of bud rot designated A, B and C are distinguished in oil palms. Types A and B show a characteristic red ring in the stem but nematodes could only be recovered from type A.

Inoculation experiments using R.R.D. tissue from type A were conducted using oil palm and coconuts of various ages. One-year-old palms did not become infested, and are less susceptible to attack; some of the palms in all the older age groups did. R.R.D. is endemic in the Yaracuy region in coconuts, oil palm and in a wild palm *Attalea* sp. The nematode *Aphelenchoides cocophilus* invades the oil palm only after it has been affected by 'Bud Rot'.

222—MANOO, S., 1963. Artificial infection studies on red ring. Root infections. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962*, 8–9.

Root inoculation of healthy coconut roots with *R. cocophilus* indicated a rapid spread of the nematode from the point of inoculation at rates of 2 ft (609 mm)/week outwards and up to 4 ft (1·2 m)/week towards the bole. Infections had reached the bole in 4–5 weeks. No difference was detected between young and old roots although nematode density was greater in the former. Aerial symptoms usually developed in the palms 12–20 weeks after inoculation.

223—MARQUES DA CRUZ, H., 1944. O Anel Vermelho nova e perigora doença dos coqueirais Alogoanoa. [Red Ring Disease a new and dangerous disease of coconuts of (the State of) Alagos.] *Boletim da Secçao de Formento Agricola no Estado Alagoas, Brazil*, **3** (7), 37–43.

224—MARQUES DA CRUZ, H., 1944. Nova e perigora Ameaca dos Coqueirais Nordestinos. [A new and dangerous threat to northeastern coconuts.] *Gazeta de Alagoas, Brazil*, 13/8/44.

225—MARQUES DA CRUZ, H., LIMA, L. T. F., 1946. Doença do anel vermelho dos coqueiros no Brasil. [Red Ring disease of coconut palms in Brazil.] *Chacaras e Quintaes*, **74**, 608.

226—MARQUEZ DELGADO, A., 1973. Plagas y enfermedades del cocotero. [Pests and diseases of the coconut palm.] *O Campo, Mexico*, **49** (980), 16–25.

227—MARTINEZ, R. G. J., 1970. *Rhynchophorus palmarum* L. (Coleoptera, Curculionidae) portador del nemátodo del 'anillo rojo' en Venezuela. [*R. palmarum* (Coleoptera, Curculionidae) carrier of the nematode of 'red ring' in Venezuela.] *Revista de la Facultad de Agronomia, Venezuela*, **5** (4), 81–85.

Rhynchophorus palmarum collected on a coconut plantation in Venezuela were examined for *R. cocophilus*. Nematodes were found in or on 47 of the 104 beetles examined.

228—MARTYN, E. B., 1952. Diseases of coconuts in Trinidad and Tobago. *Journal of the Agricultural Society of Trinidad and Tobago*, **52**, 145–149.

R.R.D. is one of three major diseases affecting coconut palms in the Caribbean area and South America, the other two are Bronze Leaf Wilt (? Lethal Yellowing or Bud Rot) and 'Unknown Disease' (Lethal Yellowing), the latter known only in the northern Caribbean. R.R.D. is of South American origin occurring only during the last 50 years in the Caribbean Islands. Symptoms are described, leaf symptoms being very similar to those of Bronze Leaf Wilt. R.R.D. is confined to young palms from 4–7 years old. No effective control is available. The palm weevil and other palm fauna are suspected transmitters.

229–MARTYN, E. B., 1953. Red ring disease of coconuts in Trinidad and Tobago. *Tropical Agriculture, Trinidad,* **30** (1/3), 43–53.

The symptoms of R.R.D. of coconuts are shown to be associated with the production of a strongly reducing substance in the periphery of the cortex of young palms invaded by *Aphelenchoides cocophilus*. The normal means of entry is by penetration through the leaf axils. It is shown that the coconut weevil, *Rhynchophorus palmarum*, is able to transmit the infection. When burrowing in the cortex of diseased palms, the weevil's legs and body become covered with infected debris which is then transferred to wounds or leaf axils of adjacent palms. Control is possible by removing all infected palms and by destroying diseased tissues by fire.

230—MARTYN, E. B., 1955. Diseases of coconuts. Their symptoms and needs for research, *Tropical Agriculture, Trinidad,* **32** (3), 162–169.

The author briefly reviews the diseases of coconuts; only two known pathogens *Phytophthora palmivora* causing bud rot and *Aphelenchoides cocophilus* causing R.R.D. are lethal. The latter kills the coconut by the toxic effects of substances produced by the nematode breeding in the stem. It may become epidemic in young palm plantations but never so in older plantings. There exist 4 diseases of unknown origin which occur as 2 groups: Bronze Leaf Wilt and the 'Unknown Disease' (now known to be one disease, Lethal Yellowing) and Root Disease ('Root Wilt disease' of India, not R.R.D.) and Cadang–Cadang.)

231—MATHEN, K., KURIAN, C., LAL, S. B., 1970. Record of *Radopholus similis* (Cobb, 1893) Thorne, 1949 and other plant parasitic nematodes from coconut palm *Cocos nucifera* L. *Science and Culture,* **36** (3), 159.

R. cocophilus causing R.R.D. is included in the lists of nematodes associated with coconuts.

232—MEDINA DUÑO, J., 1959. Cómo evitar la propagación del anillo rojo del coco. [How to avoid the spread of red ring of coconut.] *El Agricultor Venezolaño,* **23** (214), 21.

R.R.D. is a national problem in Venezuela. The variety 'Caribe' is more resistant to the disease. Plantations must be kept clean and all infected material burned. Ants, *Rhynchophorus palmarum*, termites, *Strategus alocus**, irrigation water and farm implements can all transmit the nematodes. The ants and weevil may be controlled by a Dieldrex mixture and the latter also by trapping. Spraying should not take place during the flowering of the palm, *S. alocus* may be controlled using light traps. The soil should be fumigated before replanting.

(* presumably *S. aloeus* L.)

233—MENDOZA, N. M., 1973. Algunas observaciónes en el nemátodo del anillo rojo (*Rhadinaphelenchus cocophilus* Cobb) en los estados de Guerreo y Oaxaca, Mexico. [Some observations on the red ring nematode (*R. cocophilus* Cobb) in the States of Guerrero and Oaxaca, Mexico.] *Nematropica,* **3** (2), 50–51.

R.R.D. of coconut palm caused by *R. cocophilus* is a serious problem in the Mexican states of Veracruz, Tabasco, Colima, Guerrero and Oaxaca. These studies indicate the distribution of the disease in the latter two states, the infestation being more serious in Oaxaca. The greater age, 50–80 years, of palms in Guerrero may be one reason for this situation. Eight out of 12 *Rhynchophorus palmarum*, but none of 20 *Rhinostomus barbirostris* carried nematodes on their bodies.

234—MICOLETZKY, H., 1921. Die freilebenden Erd-Nematoden. [The free-living soil nematodes.] *Archiv für Naturgeschichte, Berlin, Abteilung. A,* **87** (9) pp. 584–587.

The genus *Aphelenchus* is reviewed and two new subgenera are erected, *Paraphelenchus* and *Chitinoapnelenchus*. *Aphelenchus cocophilus* is placed in the latter.

235—MOHAMMED, S., 1962. The presence of *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960 in the gut of larvae of the palm weevil *Rhynchophorus palmarum* (L). *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* S1–S9.

Larvae of palm weevils, irrespective of their age, when fed on R.R.D.-infested coconut tissue, harboured heavy worm burdens in their guts. 100% of larvae exposed for more than 4 days contracted nematodes in their guts; only one case of infested body cavity and not gut was recorded. Abnormally high mortality of these larvae was noted compared with larvae fed on healthy coconut tissue. In dead larvae, nematodes were found in the body cavity.

236—MOHAMMED, S., 1963. Studies on the palm weevil. *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1962,* 13–14.

Observations were made on adult weevils emerging from pupae which had developed in R.R.D.-infested coconut palms. Twelve out of 13 adults carried external infections of more than 50 nematodes each, 6 out of 11 supported gut or body cavity infections. External infections may have been contracted by contamination of the pupae from the infected palm in which pupation had occurred.

237—MONTENEGRO, L., 1942. O Coqueiro. [The coconut palm.] *Boletim do Ministério da Agricultura, Brasil,* **31**, 5–10.

238—NADAKAL, A. M., 1965. Nematodes in relation to diseases of coconut palms. *Journal of Scientific and Industrial Research, New Delhi, India*, **24**, 128–135.

A review paper of nematodes associated with coconut diseases, fungal and bacterial diseases of other plants and those acting as vectors. The nematodes associated with coconuts included *R. cocophilus*.

239—NICKLE, W. R., 1970. A taxonomic review of the genera of the Aphelenchoidea (Fuchs, 1937) Thorne, 1949 (Nematoda: Tylenchida). *Journal of Nematology*, **2**(4) 375–392.

Twenty-four of the 28 described genera of Aphelenchoidea are described and figured and their differential characteristics set out. The diagnostic details are given of *Rhadinaphelenchus cocophilus* (Cobb, 1919) J. B. Goodey, 1960 in the Family Aphelenchoididae as the type and only species in the genus. The most important diagnostic features include the very long, very slender nature of the bodies of both males and females, the vulva with wide overlapping flap, the paired, unfused spicules, which are very small, with elongated apices and prominent rostra, the tip of the triangular ventral element extending slightly back over the posterior portion and the tip of the sclerotized portion of the ventral element appearing to terminate some distance from the tip of the dorsal element (as in *Parasitaphelenchus* and *Huntaphelenchoides*). These three genera should be placed in the same subfamily based on their spicular characteristics. These genera together with *Bursaphelenchus* have small terminal caudal alae. The oesophageal glands are dorsal as illustrated by Thorne (see abst. 291), rather than ventral as indicated by Goodey (see abst. 145). The Palm Weevil may act as a carrier of the nematode.

240—NICKLE, W. R., 1970. A taxonomic review of the Aphelenchoidea (Fuchs, 1937) Thorne, 1949 (Nematoda: Tylenchida). Résumés of contributions to the proceedings of the Second International Congress of Parasitology. *Journal of Parasitology*, **56** (4) Section 2, Part 1, Number 454, p. 249.

A detailed abstract of the paper is given (see abst. 239).

241—NOWELL, W., 1918. Root disease of coconut palms in Grenada. *Agricultural News, Trinidad*, **17** (434), 398–399

A historical paper giving the first record of R.R.D. outside Trinidad. The disease under study affects healthy palms in Grenada about the time that they come into bearing and has no relation to poor cultural conditions. Symptoms begin with yellowing of the leaves from the oldest; coconut weevils and bacterial bud rot are associated with the condition. A brown wet rot is seen in patches on the leaf bases. Root discolouration followed by rotting preceeds foliar symptoms. A red ring of discoloured tissue is seen in the stem of diseased palms. The condition is fatal to the palm, symptoms agreeing with those of the root disease of coconuts in Trinidad (Stockdale (absts 274–279), Rorer (abst. 254)). Rorer's report is discussed and it is confirmed that fungi and bacteria are not responsible for the condition. Nematodes in the roots are associated with all occurrences of the disease in Grenada and in some material from Trinidad. Tentative control measures are suggested including the use of stem tissue for weevil traps. The windward side of Tobago has been devastated by this disease.

242—NOWELL, W., 1919. The root disease or Red Ring Disease of coco-nut Palms. *Agricultural News, Trinidad*, **18**, 46.

In this paper the author first suggests the name Red Ring Disease in place of Root Disease. Details are given of the symptoms of attack, including the distribution of the nematode in the palm. These observations are made in Trinidad two months after publication of Nowell's original observations on the disease in Grenada and correct many of the initial findings (see abst. 241).

243—NOWELL, W., 1919. The red ring or 'root' disease of coco-nut palms. *West Indian Bulletin*, **17** (4) 189–202.

244—NOWELL, W., 1919. Red Ring Disease of coco-nuts. *Agricultural News, Trinidad*, **18**, 398.

A brief outline report of work which is dealt with in greater detail in other reports. The association between the nematode, *Aphelenchus cocophilus*, and R.R.D. is confirmed. The existence of the disease in the roots is only secondary, the centre of infestation and breeding ground being the red ring area of the stem. It appears that the infestation of the leaves brings about the death of the palm. Infestations are equally common in plantations originating from virgin forests or old cultivated land. Losses up to 30% are recorded. The time for establishment of the disease following inoculation varied from 60–74 days. The only hope of control lies in prevention and not in cure.

245—NOWELL, W., 1920. The Red Ring Disease of coco-nut palms. Infection Experiments. *West Indian Bulletin*, **18** (1–2), 74–76.

Inoculation of healthy palms, with R.R.D. tissue, in the stem, petiole or leaf axil resulted in the palms developing characteristic symptoms. Details of the inoculations are given. The results support the idea that infections originate in the leaf axils.

246—NOWELL, W., 1920. Red Ring Disease of coco-nuts. Disposition of infested material. *Agricultural News, Trinidad*, **19**, 222.

In order to destroy R.R.D.-infested palms, the pit formed by the removal of the stump should be utilized as a charcoal pit. All debris from the palm

should be buried under a layer of earth. This system permits complete burning. A cross cut saw rather than a machete should be used to minimize the danger of chips. Cutting should take place over the pit.

247—NOWELL, W., 1923. Diseases of coconut. In: *Diseases of Crop Plants in the Lesser Antilles*. The West India Committee, London, 383 pp. R.R.D. pp. 177–182.

This account brings together all the knowledge to that date on R.R.D. The historical development of the disease and its control measures are described in detail. The bud rot which develops as a symptom is not related to infectious bud rot. Symptoms of R.R.D. are described. Very little was known at that time as to the mode of spread of the disease.

248—NOWELL, W., 1924. Red ring disease of coconuts. *Proceedings of the Ninth West Indies Conference, Jamaica,* 164–172.

Nowell made a number of comments following a paper presented at the conference by Ashby (see abst. No. 5).

249—OLIVARES, R. B., 1969. Nematode problems in Colombia. *Proceedings of the Symposium on Tropical Nematology, University of Puerto Rico Agricultural Experimental Station,* 107–111.

R.R.D. caused by *R. cocophilus* is resulting in much damage to young (5–7 years) coconuts in the southern part of the Pacific coast of Colombia. The disease is less severe on the Caribbean coast. The disease has also occurred but is less severe on oil palm. The population levels of nematodes in the diseased tissues of infested oil palms are less than in coconut palms, a degree of resistance may therefore be inferred.

250—OOSTENBRINK, M., 1963. Symtomen en aaltjespopulaties in 'Red ring'-zieke cocos-en olie-palmen. [Symptoms and nematode populations in red ring diseased coconut and oil palms.] *Mededelingen van de Landbouwhogeschool en de Opzoekingsstations van de Staat te Gent,* **28** (3), 663–671.

R.R.D. limits the production of copra in Central and South America. Oil palm losses of 35% of palms have occurred over 10 years in Venezuela. A review of the symptoms and means of spread of R.R.D. in oil palm is given. The use of systemic nematicides and breeding for resistance are possibilities for research into future control.

251—PIMENTEL, G., 1944. O coqueiro da Praia. [The coconut of Praia.] *Boletim do Division do Defesa Sanidade Vegetal, Brazil,* No. 13, 120 pp.

252—PONTE, J. J. da, LIMA, J. A. A., BRANDINE, E., 1971. O anel vermelho do coqueiro, no estado do Ceará. [The red ring of coconut in the State of Ceará, Brazil.] *Pesquisas Agropecuaria Brasileira, Nordestino Recife,* **3** (2), 85–87.

The finding of *R. cocophilus* in coconut palms with red ring symptoms confirms the presence of this nematode in Ceará State, Brazil.

253—RAJNAUTH, G. L., 1973. The poisoning of Red Ring Disease trees and its role in the control of Red Ring Disease. *In:* Griffith, R. (ed.) *1973 Proceedings of the 3rd Annual Symposium for the Coconut Growers of Trinidad and Tobago,* pp. 25–31.

The importance of phytosanitation is discussed. Infested palms should be destroyed by poisoning. It is necessary to inject the poison sufficiently deep especially in R.R.D. palms to permit free movement of the chemical up the stem. When 10 ml. of Weedicide 100 or of a 1 :1 mixture of Silvisar 510 with water, are injected into a hole or holes drilled into the stem, the palm dies within 10–14 days. The removal of nematode-infested palms breaks the chain of infestation by preventing weevils from picking up an inoculum of nematodes.

254—RORER, J. B. 1911. *Report of the Mycologist for the Year Ending March 31, 1911* Part 2, Root-Disease. Trinidad and Tobago Department of Agriculture, Circular No. 4, pp. 27–33.

A paper of historical interest (R.R.D. was known at this time as Root Disease of Coconut). The root disease described from Asia is distinct from that of Trinidad; only one of the described symptoms being similar. The presence of a red ring in the tissue of the stem and rotted roots are diagnostic of the latter. This and other conditions must not be confused with Bud Rot although external symptoms are similar. The history and symptomatology of the disease are discussed, emphasis being placed on the discolouration of tissues. Microscopic examination and culturing confirmed that the disorder was not of fungal origin as suggested by Stockdale (see abst. 279). The disease makes the palm susceptible to attack by other organisms. No organism is specifically associated with the condition, the cause is probably physiological resulting from poor growing conditions, occurring frequently on coconuts planted on old sugar cane land. Control recommendations include good cultivation of the land, burning of diseased palms and the selection of resistant palms which have survived in heavily infested areas.

255—SAINT VINCENT, 1956. *Report of the Department of Agriculture, Forestry and Fisheries, St. Vincent, for the year ended December 31, 1955.* Kingstown, St. Vincent, 68 pp.

Little work has been undertaken on nematodes which are nevertheless serious pests. *Aphelenchoides cocophilus* infection of low incidence occurred on coconut palms.

256—SANCHEZ POTES, A., 1962. Estado fitosanitario de los cultivos de coco y palma africana en los litorales del Atlántico y del Pacifico (Colombia). [*The phytosanitary condition of the coconut palm and African palm crops on the Atlantic and Pacific coasts.*] Instituto de Fomento Algodonero, Bogota, 55 pp.

257—SANCHEZ POTES, A., 1964. El anillo rojo de la palma africana y del cocotero en Colombia. [The red ring of the African palm and the coconut palm in Colombia.] *Boletin de Noticias*. Instituto de Fomento Algodonero, Bogota, Colombia, **4** (10).

258—SANCHEZ POTES, A., 1964. Enfermedades del Algodonero, Cocotero y Palma Africana en Colombia. [Diseases of cotton, coconut and African palm in Colombia]. *Boletin de Noticias,* Instituto de Fomento Algodonero, Bogota, Colombia, **4** (12).

The major problems of cotton, coconut and oil palm are described. R.R.D. caused by *R. cocophilus* occurs in coconuts and oil palms in association with *Ceratocystis fimbriata*.

259—SANCHEZ POTES, A., 1966. Enfermedades del Algodonero, Cocotero y Palma Africana en Colombia. [Diseases of cotton, coconut and African palm in Colombia]. *Acta Agronomica, Colombia,* **16** (1–2), 1–13.

The text of this paper is based on the previous bulletin. (see abst. 258).

260—SANCHEZ POTES, A., 1967. El anillo rojo (*Rhadinaphelenchus cocophilus*) del cocotero en la zona de Tumaco. [Red-ring disease (*R. cocophilus*) of coconut palm in the region of Tumaco.] *Agricultura Tropical Colombia*, **23** (7) 433–449.

At Tumaco in the Colombian Department of Nariño, R.R.D. affected coconut palms more severely than oil palms (*Elaeis guineensis*), and the differences in internal symptoms in the two types of palm are described. *Rhynchophorus palmarum* (L.) appeared to be the vector of *R. cocophilus*. Recommendations for the control of both the vector and the nematode are given, based on results obtained in other countries.

261—SANCHEZ POTES, A., KAFURE, J. V., 1970. Control del anillo rojo. [Control of the red ring.] *Boletin Agricola (Colombia),* No. 596, 928–930.

262—SERVICIO SHELL PARA EL AGRICULTOR, 1958. Hacia el control del 'anillo rojo del cocotero'. [Towards the control of red ring disease of the coconut palm.] *Noticias Agricolas, Venezuela,* **29**, 3–4.

263—SERVICIO SHELL PARA EL AGRICULTOR, 1973. Con el control del coco cigarron o picudo se evita la incidencia del 'anillo rojo' en los cocales. [With the control of the coconut borer or weevil the incidence of red ring can be eliminated in the coconut plantations.] *Noticias Agricolas,* **6** (32), 127–129.

It is necessary to control *Rhynchophorus palmarum* L. in coconut plantations in Venezuela both because the adults are vectors of the nematode (*R. cocophilus*) that causes R.R.D. and because the larvae destroy the young growth of the palms and facilitate the entry of secondary pest organisms. It is recommended that all adults should be removed from the plantations. Cylindrical traps (diameter 0.5 m, height 1 m) constructed of wide-mesh wire netting should be placed among the palms at a rate of 2–4/ha. They should be baited with material from palms affected by R.R.D. and the lower half of the trap poisoned with methomyl (Lannate) at 1 g/l of water. The traps should be emptied and rebaited at least every eight days and the old debris and adults removed from the plantation and destroyed. It is also recommended that as soon as palms show signs of R.R.D. they should be killed by the injection of a chemical such as sodium arsenite or Daconate at 60 and 100 ml/palm respectively, and removed to eliminate possible sites for the development of the pest.

264—SERVICIO SHELL PARA EL AGRICULTOR, 1973. Control del anillo rojo del cocotero. [Control of red ring of coconut.] *Noticias Agricolas, Venezuela,* **6** (27), 110.

It has been estimated that 40% of the coconut palms in Venezuela are affected by the R.R.D., caused by the nematode *R. cocophilus*, of which the beetle *Rhynchophorus palmarum* L. is the vector. The symptoms of the disease, the transmission of the nematode and measures to limit its dispersal are outlined.

265—SHARPLES, A., 1926. Diseases of the Coco Nut Palm II. *Malayan Agricultural Journal,* **14**, 91–95.

Following Thompson's report (abst. 290) the symptoms of three diseased coconut palms in Malaya are described; they resemble those described by Nowell (see abst. 247) for R.R.D., except that the red discolouration is always central in the stem and that no nematodes could be recovered from diseased tissue. (R.R.D. has never been confirmed from Malaya.)

266—SHARPLES, A., 1928. Palm diseases of Malaya. *Malayan Agricultural Journal,* **16** (9–10), 313–360.

The author reports two further cases (see abst. 265) of diseased palms in Malaya whose symptoms resemble those of R.R.D. as defined by Nowell. Again the discolouration is central in the stem and no nematodes could be isolated.

267—SINGH, N. D., 1970. A survey of the Red Ring Disease of coconuts in the Pomeroon River. *Agricultural Research, Guyana,* **4**, 164–171.

Low yield and crop failure are due to bud rot caused by *Phytophthora palmivora* and R.R.D., due to *R. cocophilus*, accounting for 30% and 7% respectively; *Strategus aloeus* and the large moth borer *Castnia daedalus* accounted for 6% of palm deaths. Distinction is made between crown- and root-infected palms. *R. cocophilus* was found in only one soil sample. Infected palms, all 5–10 years old, were often found in groups on low-lying ground. Bud rot infected palms were 3–15 years old. Poor soil drainage accounted for the poor growth and abandonment of areas along the river bank. Symptoms of Pencil Point Disease are seen in these areas. Toxic soil condition is another possible reason for palm deaths as well as poor management. The palm 'Cokerite' is said to be resistant to R.R.D.

268—SINGH, N. D., 1971. A survey for the causes of the early death of coconut palms (*Cocos nucifera* L.) in the Pomeroon River area, Guyana. *Nematropica* **1** (1) English, 17, Spanish, 36–37.

7% of coconut palms in the Pomeroon River area of Guyana died as a consequence of R.R.D.

269—SINGH, N. D., 1972. A survey of red ring disease of coconut palm in Grenada, West Indies, *Plant Disease Reporter*, **56** (4), 339–341.

A survey of coconut in Grenada for R.R.D. showed that 22·3% of palms were infected. The palm weevil was present in 92% of these infections. 72% of the palm weevils were infested with R.R.D. nematodes. There was no relationship between weevil sizes and their infestation with R.R.D. nematodes. (See absts. 50, 157.)

270—SINGH, N. D., 1973. Survey of red ring disease in Grenada. *In:* Griffith, R. (Ed.) 1973. *Proceedings of the 3rd Annual Symposium for Coconut Growers of Trinidad and Tobago,* 82–87.

The results are given of a survey, based on random sampling and trapping of weevils in major production areas, to determine the severity of R.R.D. caused by the nematode *R. cocophilus* and transmitted by the vector *Rhynchophorus palmarum*. A mean of 22%, range 0–73·6%, of palms 2–15 years old were infected with R.R.D. The palm weevil was associated with R.R.D. in 92% of cases. About 12% of R.R.D.-positive palms showed no visible symptoms. 72% of the weevils collected were infested with the nematode. Bud Rot was caused by *Phytophthora palmivora, Castinia daedalus* and *Oryctes rhinoceros* L. were also reported. (The latter has never been reported from the American continent and is probably a *Strategus* sp.) Singh (misquoting Griffith), reports that a 0·1% Lannate solution kills all the weevils in a palm when sprayed into the axils. Lannate-treated traps are also recommended. The Malayan Dwarf Coconut is said to be highly resistant to R.R.D. (not confirmed elsewhere).

271—SNYDER, T. E., ZETEK, J., 1924. Damage by termites in the Canal Zone and Panama and how to prevent it. *USDA Bulletin No. 1232, Washington, D.C.*

A 5 year old coconut palm inoculated with R.R.D. nematodes by Cobb died 6 months later showing the characteristic symptoms of R.R.D. A secondary nest of *Coptotermes niger* Snyder containing only soldiers and workers was found within the stem. Individual termites carried nematodes on their bodies. The possibility of mechanical transmission of R.R.D. by termites is suggested. *Leucotermes tenius* Hagen, *Nasutitermes ephratae* Holmgren and *Eutermes* sp. were also working and nesting inside coconut palms. *N. ephratae* was also found in a fan palm.

272—STEMERDING, S., KUIPER, K., HOUTMAN, G., 1968. Aaltjes in land en tuinbouw. [*Eelworms in agriculture and horticulture.*] *Tjeenk Willink, Holland,* p. 79.

R.R.D. of coconut and oil palm is caused by the nematode *R. cocophilus*. It is spread by the coconut weevil *Rhynchophorus palmarum*. In Surinam it is associated with little leaf disease.

273—STEWART, F. H., 1921. The anatomy and biology of the parasitic Aphelenchi. *Parasitology,* **13**, 160–179.

A. cocophilus is not referred to as a parasitic aphelench. The limited survival in the soil of other species is discussed as is their mode of entry into the host plant via leaves, wounds or stomata. (This resembles the suggestions made for *A. cocophilus* by Esser and Goodey) (see absts. 62 & 147).

274—STOCKDALE, F. A., 1907. Coconut Palm Disease. *Proceedings of the Agricultural Society of Trinidad and Tobago,* **7**, 9–31.

A paper of historic interest which reports one of the first visits of a pathologist to study Root Disease (R.R.D.) of coconuts in Trinidad. A Mr. Busck of U.S.D.A. is said to have visited the islands in 1905 and reported on the coconut disease. In addition to Root Disease (R.R.D.), a fungal Leaf Disease, a bacterial Bud Rot, scale insect, a beetle and locusts are reported to be attacking coconuts. Root Disease is considered to be of fungal origin, a *Botryodiplodia* sp. being implicated. The presence of a red ring is noted which commences at the base of the palm. A detailed description of symptoms and control measures, based on the hypothesis of a fungal origin for the condition, is given. Search for disease-resistant varieties from endemic areas is recommended.

275—STOCKDALE, F. A., 1907. Disease of coconut plants. *Agricultural News,* **6**, 75.

276—STOCKDALE, F. A., 1907. Report of a visit of F. A. Stockdale to Trinidad to examine a reported disease of coconuts. *Royal Gazette Trinidad,* (February 14), **11**, 349–363.

The text of this report was later reprinted in the *West Indian Bulletin* (abst. 279).

277—STOCKDALE, F. A., 1907. Cocoa-nuts. In the Presidential Address by Sir Daniel Morris to the 6th West Indian Agricultural Conference, Jamaica. *West Indian Bulletin,* **8** (1), 330–331.

The Imperial Department of Agriculture is investigating the major diseases of coconuts in Jamaica, Trinidad and British Guiana. The mycologist is in Trinidad (studying R.R.D.). The coconut industry could be extended as a result of increasing demands if these diseases can be kept in check.

278—STOCKDALE, F. A., 1909. Fungus diseases of Coco-nuts in the West Indies. *Pamphlet of the Agricultural Society.*

(See abst. 279.)

279—STOCKDALE, F. A., 1909. Fungus Diseases of coconuts in the West Indies. *West Indian Bulletin,* **9**, 361–371.

Root disease (R.R.D.), Leaf disease and Bud Rot of coconuts are described in detail. All are considered to be of fungal origin. The symptoms of root disease are described including reference to the development of a Red Ring whose location is more central when the leaves first affected are more central. The disease is more prevalent in low, poorly drained areas. Control recommendations include the cutting and burning of all infected palms, including dead leaves, husks and the stump and roots; the isolation of the area by trenching; the resting of the land before replanting; the use of a leguminous ground cover 'to improve the condition of the soil' and the possible use of crop rotation before replanting. The use of fungicidal sprays on the soil is also recommended as are improved cultivation and the search for resistant varieties. A variety termed 'Green Spanish' is more tolerant. (Confusion existed at this time as to the distinction between Root disease (R.R.D.) and Bud rot.)

280—SURINAM, 1969, 'Landbouwproefstation Suriname. Jaarverslag 1968'. [Surinam Agricultural Research Station. Annual Report 1968.] *Mededelingen Landbouwproefstation Suriname,* No. 44, 156 pp. Plant nematodes pp. 139–153.

When *R. cocophilus* was inoculated into the palms *Mauritia flexuosa* and *Maximiliana maripa,* red ring symptoms developed, but these palms have not been found infested in the wild. When pieces of stem tissue of these palms, coconut palm and oil palm were inoculated, the nematodes colonized them.

281—SURINAM, 1973. 'Landbouwproefstation Suriname. Jaarverslag 1970.' [Surinam Agricultural Research Station. Annual report 1970.] *Mededelingen Landbouwproefstation Suriname,* 141 pp.

Nutrition studies on coconut and oil palms are described. R.R.D. and Coconut Wilt were also reported from Surinam.

282—SURINAM, 1974. 'Landbouwproefstation Suriname. Jaarverslag 1972.' [Surinam Agricultural Research Station. Annual report 1972.] *Mededelingen Landbouwproefstation Suriname,* 67 pp.

Reports are included on studies on *Castnia* spp., R.R.D., Bud Rot and an unidentified wilt in the Coronie area (coronie wilt).

283—SURINAM, 1974. 'Landbouwproefstation Suriname. Jaarverslag 1973.' [Surinam Agricultural Research Station. Annual report 1973.] *Mededelingen Landbouwproefstation Suriname,* 76 pp.

Control of *R. cocophilus*, bud rot and weeds is described. Fertilizer trials on coconuts were undertaken.

284—TARJAN, A. C., 1960. *Checklist of plant and soil nematodes. A nomenclatorial compilation.* University of Florida Press, 200 pp. see p. 29.

The chronological changes in the generic and subgeneric identity of *R. cocophilus* are given as: *Aphelenchus* Cobb 1919 (abst. 38); *Aphelenchus (Chitinoaphelenchus)* Cobb, 1919 (abst. 234); *Aphelenchoides* (Cobb, 1919) Goodey, 1933 (abst. 150); *Aphelenchoides (Aphelenchoides)* Cobb, 1919 Goodey, 1933 (abst. 116a); *Aphelenchoides (Chitinoaphelenchus)* (Cobb, 1919) Goodey, 1933; *Chitinoaphelenchus* (Cobb, 1919) Chitwood in Corbett, 1959 (abst. 43).

285—TARJAN, A. C., 1967. *Supplement 1. (1961–1965) to the check list of plant and soil nematodes. A nomenclatorial compilation.* University of Florida Press, 115 pp, see p. 15.

Generic and subgeneric changes from 1961–1965 are given as: *Rhadinaphelenchus* (Cobb, 1919) Goodey, 1960 (abst. 143).

286—TARJAN, A. C., HOPPER, B. E., 1974. *Nomenclatorial Compilation of Plant and Soil Nematodes.* Society of Nematology, 419 pp. see p. 59.

The details given here are as given by Tarjan (see abst. 284 and 285).

287—TENORIO, R. P., 1948. Anel vermelho do coqueiro em Pernambuco. [Red Ring Disease of

the coconut in Pernambuco.] *Boletim da Secretaria da Agricultura, Industria e Comercio. Pernambuco,* **15** (1), 204–220.

R.R.D. is reported from the State of Pernambuco in Brazil. *Roystonea regia* is reported as an alternative host for *R. cocophilus*.

288—THAMPAN, P. K., 1975. *The coconut palm and its products.* Green Villa Publishing House. Cochin 11, India, 302 pp.

A brief account of R.R.D. of coconut palms, due to *R. cocophilus,* and its control is included.

289—THIRUMALACHAR, M. J., 1946. Bud rot of areca palms in Mysore. *Nature, London,* **157**, 106–107.

The author reports a disease condition of coconuts in India resembling R.R.D. and tentatively identifies nematodes isolated from the coconut palm as *Aphelenchoides cocophilus* (the identity has not been confirmed as such).

290—THOMPSON, A., 1924. Annual report of the Mycologist for 1923. *Malayan Agricultural Journal,* **12**, 246, 251.

On the basis of external symptoms R.R.D. was the possible cause of a disease of coconut palms in Malaya. The R.R.D. nematode was not found. (See also absts. 265, 266.)

291—THORNE, G., 1961. *Principles of Nematology.* McGraw-Hill N.Y., 553 pp. (R.R.D. pp. 428–431).

Diagnosis of the genus *Rhadinaphelenchus* Goodey, 1960 belonging to the subfamily Aphelenchoidinae and of the only species *R. cocophilus* (Cobb, 1919) J. B. Goodey, 1960 are given with original illustrations. A brief history of R.R.D. is given. External symptoms are said to be non-specific with yellowing or browning commencing at the basal leaves. 'Leaves split lengthwise and exhibit yellow to dull red streaks and mottling along a branch . . .'. (This is an internal symptom seen in the petiole when it is split.) The distinctive internal symptoms are described. Thorne felt that there was no conclusive evidence that nematodes pass from the roots to the stem or vice versa, despite the characteristic symptoms of root infections described. The importance of *Rhynchophorus palmarum* as a transporter (externally) of the nematode is described. Outbreaks of R.R.D. following periods of heavy rain are explained by the movement of the nematode up the outside of the trunk from the soil. Cabbage and Gru-gru palms are quoted as alternative hosts of the nematode. When the latter was inoculated in the crown, it took 8 months for the infection to reach the base. R.R.D. is widely distributed in tropical America. Thorne describes and illustrates 4 pairs of papillae on the male tale. (Cobb (see abst. 38) and Goodey (see abst. 143) describe only three pairs. They exclude Thorne's first post-anal pair. Brathwaite and Siddiqi (see abst. 28) agree with Thorne.)

292—THURSTON, H. D., 1973. Threatening plant diseases. In: Baker, K. F. (Ed.) *Annual review of Phytopathology,* **11**, 27–52.

R. cocophilus is mentioned as a disease agent of intermediate threat potential. So far it is confined to the Americas.

293—TIDMAN, D. A., 1951. Some Agricultural and Horticultural Problems in Brazil. *Plant Protection Overseas Review,* **2**, No. 4, 20–32.

Rhynchophorus palmarum, apart from being a problem of coconuts in its own right, is also the agent for the transmission of *Aphelenchoides cocophilus* which causes R.R.D. The nematode was found in the intestine of all of 'many thousands' of weevil larvae dissected. It is also passed out with the faeces which fall to the ground. Nematodes from these faeces then enter the coconut palm in the root system. Palms so infected die within four years. The characteristic symptoms of R.R.D. are described. Control of the weevil using BHC, DDT, Parathion (Rhodiatox) and arsenical dusts has proved unsuccessful. Soil fumigation with DDT has controlled the nematode while it is living free in the soil.

294—TIDMAN, D. A., 1951. Agricultural and horticultural problems of Brazil. *World Crops,* **3** (9), 341–344.

Rhynchophorus palmarum causes considerable damage to coconut palms in Brazil, Trinidad, Belize, Panama, Venezuela and Costa Rica. The larvae of the palm weevil transmit *R. cocophilus* while feeding on green plant tissue and by way of infested faecal pellets which fall to the ground. The nematodes then enter the plant via the root system. External and internal symptoms are described. Soil fumigation with D–D controls the nematode in the soil. BHC and DDT are ineffective and nicotine sulphate, parathion, and arsenic dusts are only slightly effective in controlling the weevil. *Rhina barbirostris* attacks the more mature parts of older palms.

295—TOLER, R. W., CUELLAR, S. R., FERRER, J. B., 1959. Preliminary survey of plant diseases in the Republic of Panama, 1955–1958. *Plant Disease Reporter,* **43** (11), 1201–1203.

During this survey *Aphelenchoides cocophilus* was recorded on *Cocos nucifera.*

296—TORREALBA, P. A., 1969. Survey of plant-parasitic and free-living nematode genera from Venezuela. In: Peachey, J. E. (Ed.), *Nematodes of tropical crops.* Technical Communication of the Commonwealth Bureau of Helminthology, No. 40, pp. 257–263.

R. cocophilus was found to be causing serious damage to coconut palms.

297—TRINIDAD AND TOBAGO, 1926. *Report of the Department of Agriculture for the year ending 31 December 1925.* Government Printing Office, Trinidad, p. 32.

R.R.D. still occurs in epidemic form in some areas 'in inverse proportion to the thoroughness of the action taken to control it'. No curative measure is possible due to the speed with which the palm dies after symptoms appear. As plantations mature, the incidence of R.R.D. decreases.

298—TRINIDAD AND TOBAGO, 1952. Diseases of economic plants in Trinidad and Tobago. Coconuts. *Bulletin Number 2, new series, Ministry of Agriculture, Trinidad,* 13–16.

Of 3 diseases affecting coconuts in Trinidad and Tobago, R.R.D. affecting young palms and Bud Rot are less important than Bronze Leaf Wilt. External symptoms of R.R.D. resemble those of the latter condition. The diagnostic and only distinctive feature of R.R.D. is the presence of the red ring with its nematodes. In areas where major replanting programmes take place it may become a serious problem.

299—TRINIDAD AND TOBAGO, 1958. *Administration report of the Agricultural Department for the year 1957.* Trinidad, 49 pp.

The Agricultural Department reports that investigations into R.R.D. caused by *Aphelenchoides cocophilus* are being initiated.

300—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1962. *Annual Report of the Research Station for the year 1961, Trinidad,* 203 pp.

Details of the report are listed under the contributing authors. (See abst. Nos 73, 74, 91, 92, 93, 94, 95, 105, 106, 107, 208, 235.)

301—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1963. *Annual Report of the Research Station for the year 1962, Trinidad,* 42 pp.

Details of the report are listed under the contributing authors. (See abst. Nos 108, 109, 110, 114, 209, 210, 236.)

302—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1965. *Annual Report of the Research Station for the years 1963–1964, Trinidad.*

Details of the report are listed under the contributing authors. (See abst. No. 77.)

303—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1966. *Annual Report of the Research Station for the years 1964–1965, Trinidad,* 87 pp.

Details of the report are listed under the contributing authors. (See abst. Nos 78, 100, 101, 102, 103, 104, 112, 113, 214, 215, 216.)

304—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1969. *Annual Report of the Research Station for the years 1966–1968, Trinidad,* 66 pp.

Details of the report are listed under the contributing authors. (See abst. Nos 86, 87, 88, 89, 218, 219.)

305—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1972. Outlook: Red Ring Disease. *Report of the Research Station 1969–1972, Trinidad,* 5–6.

An examination of the present position is given at the termination of the research programme of the Trinidad and Tobago Coconut Research Ltd. R.R.D. research has been undertaken there for 12 years. The first control recommendations made were basically phytosanitary; the poisoning of diseased palms and the trapping of the palm weevil both by the application of insecticide to palms and by the use of traps. The degree of disease control is inadequate. Newer methods of fumigation of cut palm stems using methyl bromide and the use of systemic and non-systemic insecticides/nematicides are not effective. The present trapping methods do not effectively reduce populations of weevils. The possibility of another mechanism of transmission, other than the palm weevil, still exists.

Breeding for disease resistance or developing a cure for infected palms are the long range solutions. New plantings on fields not previously in coconuts, which had been ploughed, harrowed and properly drained produced disease-free plantations suggesting that sunlight, good land preparation and the absence of old (? diseased) root systems may be important factors. R.R.D. is still the principal long term problem of the coconut industry and its continued presence discourages farmers from growing coconuts.

306—TRINIDAD AND TOBAGO COCONUT RESEARCH LTD., 1972. Red Ring Disease. *Report of the Research Station 1969–1972, Trinidad,* 8–27.

Trials were conducted on the field evaluation of chemicals applied to leaf axils of coconut palms: Sevin (mixed with coconut husk as Cocosev) Basudin (diazinon), Temik, Nemacur and D–1410 and soil application of Temik, Nemacur and D–1410. None of the trials reduced the level of R.R.D. below loss of 5 palms/acre/year. Trials using 'standard recommendations' of poisoning palms, with Weedicide or Silvisar, and trapping weevils did not reduce losses below 10 palms/acre/year against a calculated loss of more than 15–17 palms/acre/year in untreated fields. The soil applications produced little or no protection for the palms. Nematicide content in the leaves of soil-treated palms was low and inconsistent. Of 6 trials with Cocosev, 3 were terminated due to the high incidence of R.R.D. in the plantation. In the others protection was not obtained. Low wet ground is more favourable for disease and the

possibilities of root infection seem good following the failure of Cocosev treatment of axils to control the disease.

A series of trials using standard recommended control measures failed to reduce the rate of loss below 6–7 palms/acre/year. An additional mechanism of spread of R.R.D. apart from the palm weevil may still exist. A method is also needed for the destruction of infected palms which destroys the nematode more quickly and retains insecticidal properties until the trunk is entirely decomposed.

307—VELIS, M., DEAN, C. G., 1976. El Picudo del Cocotero. [The weevil of the coconut palm.] *Ministerio de Agricultura y Ganaderia, El Salvador, Circular number 1.*

The palm weevil *Rhynchophorus palmarum* is the major pest of coconuts in El Salvador and is the major transmitter of the R.R.D. nematode. The life cycle of the weevil and methods for its control are described. Controlling the weevil is the only means presently available for controlling R.R.D. Control is obtained using a modified split log trap consisting of a pile of 6–8 pieces of coconut stem 1 metre long treated with either a 5 g/gallon solution of Lannate or 8 g/gallon of Dipterex. All infested palms should be burned. Coconut palm stems should not be used for posts as these provide a favourable breeding ground for the insects which spread R.R.D. *Xanthopygus cognatus* may serve as a biological control agent by eating the eggs and larvae of the palm weevil. *Rhinostomus barbirostris* a transmitter of R.R.D. produces similar damage in coconut palms; the differences are described.

308—VENEZUELA, 1974. Controlada nueva plaga que ataca a cocotales. [New pest of coconut plantations controlled.] *La Vida Rural, Venezuela,* Octubre 1974, p. 20.

309—VICTORIA, K. J. I., 1971. Eradication as an effective control for red ring disease of coconut palm caused by *Rhadinaphelenchus cocophilus* (Cobb, 1919) Goodey, 1960. *Nematropica,* **1** (1), English 8–9, Spanish 27–28.

Partial control of R.R.D. in Colombia is possible by the removal and destruction of infected palms.

310—VICTORIA, K. J. SANCHEZ POTES, A., BARRIGA, O. R., 1970. Erradicación de palmas de cocotero afectadas por el anillo rojo (*Rhadinaphelenchus cocophilus* (Cobb 1919), Goodey 1960, Nematoda: Aphelenchoididae), mediante la utilización de sustancias quimicas. [Eradication of coconut palms affected by the red ring (*R. cocophilus* (Cobb, 1919), Goodey, 1960 Nematoda: Aphelenchoididae) using chemical substances.] *Revista del Instituto Colombiano Agropecuaria,* **5** (3), 185–197.

Weedicide (sodium and potassium arsenite), Tordon 101 (picolinic acid with 2, 4–D) and Penite (arsenic pentoxide) were injected into the stems of R.R.D. infected coconut palms in Colombia, in tests to assess the efficacy of these chemicals in killing both palms and nematodes as an alternative to cutting and burning. Doses used were 20, 30, 40, 50, 60, and 70 ml. of chemical per palm. Details of methods of application are given. Penite killed palms the quickest—96·4% in 2 weeks at a dosage of 30 ml but Weedicide had the best nematicidal activity, 76·7%, by the 9th week at 40 ml. Taking into account toxicity to users and the economics of application Weedicide at a minimum dose of 40 ml is recommended for eradicating an infected palm.

311—VILARDEBO, A., 1971. Aperçu sur quelques nématoses des cultures tropicales. Les nématoses du cocotier. [Survey of nematode diseases of tropical crops. Coconut nematodes.] In: *Les nématodes des cultures. Journées francaises d'études et d'information, Paris,* pp. 475–479.

Damage to coconut by *R. cocophilus* is described: previously only known on coconuts in Trinidad, it is now found in other Caribbean islands, in Central America and in Colombia on the oil palm. Symptoms of attack and transmission by *Rhyncophorus palmarum* are noted. Control is discussed but no effective control measure is known. The use of insecticides against the beetle vector affords some control but must be carefully timed.

312—VILLAMIL, R. V., 1967. El anillo rojo del cocotero. [The red ring of the coconut palm.] *Revista Nacional de Agricultura, Colombia,* **61** (747), 43–45.

The symptoms, methods of dissemination, morphology and biology of R.R.D. and *R. cocophilus* are described from the literature. *Rhynchophorus palmarum,* the primary transmitter, is described in detail. The weevil is said to be positively chemo- and phototropic. Rainwater and infected seed are described as alternative methods of transmission of the nematode in addition to ants and *Rhinostomus barbirostris.* Control measures include: restraint from using fruit recovered from the bases of infected palms, the prevention of excessive humidity, the maintenance of well drained soil, the maintenance of plants at 8–10 metre distances, the burning of all infected material and the fumigation of the soil. A seed dip treatment with chlordane or formalin is also recommended, as is control of the insect transmitter.

313—WALLACE, H. R., 1973. *Nematode ecology and plant disease.* Edward Arnold, London. ix + 228 pp. See pp. 56–57.

The production of tyloses blocking the vascular tissue of coconut palms is briefly compared with that produced in cabbage roots by *Pratylenchus penetrans* and by fungi. In the latter case, such production may reduce the spread of spores through the plant.

314—WEBSTER, B. N., GONZÁLEZ, J., 1959. Investigaciones sobre la enfermedad 'anillo rojo' en cocos y palma de aceite. [Investigations on R.R.D. in coconut and oil palms.] *9th Convencion de la Asociacion Venezolana el Avance de la Ciencia, Servicio Shell para el Agricultor, Estado Arajua, Venezuela.*

315—WEBSTER, J. M., 1972. *Economic Nematology*. Academic press, London. x + 563 pp. See p. 315.

The author quotes Van Hoof and Seinhorst's 1962 report for the consistent relationship between symptoms of 'little leaf' and the nematode *R. cocophilus* in coconut and oil palm in Surinam and Guyana, and the occurrence of a severe disease of oil palm in Venezuela. In parts of the West Indies this nematode causes R.R.D. which is typically a condition of palms less than 20 years old and carrying non-specific external symptoms. Fenwick's concept of root infection and Blair and Darling's (abst. 25) opinion as to the crown of the palm being the primary site of infestation of nematodes carried by the palm weevil are referred to. Control is by eradication of diseased palms, and the discontinuation of cultural practices which damage roots and spread nematode-infested tissues.

316—WEERDT, L. G. VAN, MARTINEZ, A. P., ESSER, R. P., 1959. Results of a survey designed to determine the etiology of 'Lethal Yellowing' of *Cocos nucifera* L., *Proceedings of the Florida State Horticultural Society,* **72,** 421–430.

Many nematodes, but not *R. cocophilus,* were recovered from soil samples taken around diseased and healthy coconut palms in Florida, U.S.A.

317—WHITEHEAD, R. A., 1966. *Sample survey and collection of coconut germ plasm in the Pacific Islands*. Ministry of Overseas Development, Overseas Research Publication, Number 16, *Her Majesty's Stationery Office, London,* 78 pp.

In the introduction, Whitehead records that R.R.D. is one of the two major diseases of coconuts in the Neotropics, the other being Lethal Yellowing (L.Y.). The selective breeding programme to establish varieties resistant to L.Y. has been augmented by this collection of coconut varieties from various parts of the world. L.Y. resistance has already been found in Malayan Dwarf varieties. It was intended to extend this programme to cover R.R.D. resistance studies. Despite the views of some people that such a project would be a long term one, 'other approaches may be equally long term'. (To date, 12 years later, only one small trial related to this project has been conducted (see absts. 287, 288) to search for R.R.D. resistance.)

318—WILSON, M. E., 1962. Preliminary laboratory investigations into the life history of the Palm Weevil *Rhynchophorus palmarum* (L). *Annual Report of the Trinidad and Tobago Coconut Research Ltd. for the year 1961, Trinidad,* N1–N12

Split log traps are not an effective method of control for the weevil.

319—WILSON, M. E., 1962. Laboratory studies on the life history of the Palm Weevil. *Journal of the Agricultural Society of Trinidad and Tobago,* **62** (2) 177–194.

The palm weevil is a vector of the nematode causing R.R.D. A detailed account of the life cycle of the weevil is given.

320—WILSON, M. E., 1963. Investigations into the development of the Palm Weevil *Rhynchophorus palmarum* (L.) *Tropical Agriculture, Trinidad* **40** (3), 185–196.

Species of Palm Weevil of the genus *Rhynchophorus* are serious pests of coconuts in various parts of the world. *R. palmarum* which occurs in the West Indies and Central America is a possible vector of R.R.D. A detailed account of the life history of the weevil is given.

321—WINSLOW, R. D., 1960. Some aspects of the ecology of free-living and plant-parasitic nematodes. In: Sasser, J. N. and Jenkins, W. R. 1960. *Nematology. Fundamentals and recent advances*. University of North Carolina Press, Chapel Hill, USA. xv + 480 pp. See pp. 367–368.

Aphelenchoides cocophilus the causal agent of R.R.D. in Trinidad, Tobago and Brazil is also recorded (erroneously) as a pest of areca palm in India. The description of the disease is based on the work of Fenwick (abst. 65). The disease is almost entirely soil borne, weevils playing an insignificant part. Symptoms and the distribution of nematodes in the palm are illustrated and described. The disease in India takes a different form, the main symptom being a bud rot. Thirumalachar 1946 (abst. 289) is responsible for this report and the identity of the nematode described tentatively as *A. cocophilus* awaits confirmation. (The nematode concerned was never confirmed as *A. cocophilus*).

322—YEPEZ, T. G., MEREDITH, J. A., 1970. Nemátodos fitoparásitos en cultivos de Venezuela. [Plant parasitic nematodes of crops in Venezuela.] *Revista de la Facultad de Agronomia,* **5** (4), 33–80.

Plant-parasitic nematodes in Venezuela are listed under host plant and locality, based on a study of 660 soil and root samples from the principal agricultural regions and on information from other workers and in publications. *R. cocophilus* is the most important nematode problem in the country after *Meloidogyne* spp.

INDEXES

The reference is to the serial number of the annotation, not to the page number.

CO-AUTHORS

Abrego, L. 45
Barreto, A. C. 44
Barriga, O. R. 310
Brandine, E. 252
Christie, J. R. 46
Cuellar, S. R. 295
Darling, H. M. 25
Dean, C. G. 307
Esser, R. P. 316
Fedon, C. S. A. 6
Ferrer, J. B. 295
Filho, J. C. 44
Franklin, M. T. 146
Goderdhan, L. C. 114
González, J. 314
Hoestra, M. 201
Hoof, H. A. van 194
Hopper, B. E. 286
Hooper, D. J. 146
Houtman, G. 272
Imambaks, M. J. 205
Jiménez, O. D. 122
Kafure, J. V. 261
Khan, A. M. 184
Kuiper, K. 272
Kurian, C. 231
Lal, S. B. 231
Lima, J. A. A. 252
Lima, L. T. F. 225
Lyon, H. H. 220
Maharaj, S. 90–104, 114
Marques da Cruz, H. 115, 116
Martinez, A. P. 316
Meredith, J. A. 322
Mijailova, P. T. 52, 53
Mohammed, S. 104–114, 138
Nucé de Lamothe, M. 121
Oostenbrink, M. 48
Ouden, H. den 195
Patiño, B. 45
Premachandran, D. 193
Sánchez Potes, A. 7, 8, 310
Schuurmans Stekhoven, J. H. 117
Seinhorst, J. W. 178
Siddiqi, M. R. 28
Sosamma, V. K. 193
Stockdale, F. A. 175
Velis, M. 49, 50, 51
Woudenberg, J. R. 205
Zamith, A. P. L. 200
Zetek, J. 271
Ziller, R. 121

SUBJECT INDEX

Alternaria tenuis 124
Alternative hosts
of palm weevil 172
of R.R.D. nematode
Acrocomia aculeata 28
A. intumescens 146
Attalea sp. 221
Cabbage palm 5, 291
Elaeis sp. 115, 196
E. guineensis 28, 37, 46, 62, 115, 117, 119, 146, 149, 150, 202, 203, 204, 205, 207, 221, 249, 250, 256, 257, 258, 259, 260, 272, 280, 281, 311, 314, 315
Gru-gru palm 5, 291
Mauritia flexuosa 28, 203, 204, 280
Maximiliana maripa 28, 203, 204, 280
Phoenix sp. 196
P. canariensis 62
P. dactylifera 37, 46, 62, 115, 117, 119, 146, 149, 150, 207
Roystonea sp. 196
R. oleracea (=*Oreodoxa oleracea*) 25, 28
R. regia (=*Oreodoxa regia*) 62, 119, 146, 287
Weeds 29
erroneous report
Fig tree 117
Amaranth 128, 133, 134
Anthocyanins 21
Aphelenchoides (C) ormerodis 36, 43
A. parietinus 36
Aphelenchoididae 184, 239
Aspidiotus destructor 170
Attalea cohune 58
Attractants
for palm weevil 39, 50, 210
for R.R.D. nematode 22

Bacteria
on coconut palms 176, 177, 238, 241, 274
on palm weevil 160
Beetle 274
Bitumen 20
Bleeding stem disease 119
***Botryodiplodia* sp.** 10, 274
Bronze leaf wilt 29, 30, 119, 121, 228, 230, 298
Bud rot 10, 29, 31, 120, 160, 164, 175, 185, 190, 196, 221, 228, 230, 247, 254, 267, 270, 274, 279, 282, 283, 298
***Bursaphelenchus* sp.** 239

Cacao 15
Cadang-Cadang 230
Carbon dioxide 20, 21, 22, 24
***Castnia* spp.** 282
C. daedalus 267, 270
Ceratocystis fimbriata 258
Chemotropism
palm weevil 312
Citrus 15
Coconut fever 177
Coconut palm
origin 189
varieties
Caribe 232
Ceylon Tall 187, 188
Cokerite 267
FMS (see Malayan Tall)
Green Spanish 279
Jamaica Tall 50, 51, 187, 188
Malay Giant 129
Malayan Dwarf 270, 317
Malayan Tall 187, 188
Panama Tall 50, 51
Rennell Island Tall 187, 188
Solomon Island Tall 187, 188
Coconut wilt 281
Control
chemical
herbicides
arsenic pentoxide 310
arsenic trioxide 94, 180, 211
bromacil 180
cacodylic acid 7, 8, 179, 180
2,4-D 7, 8, 180, 310
Daconate 179, 263
Konesta 179
MSMA 179, 180
Penite 310
Picloram 7, 8
picolinic acid 8, 310
Silvisar 84, 179, 253, 306
sodium arsenate 7, 180
sodium arsenite 263
2,4,5-T 180
TCA 179, 180
Tordon (picloram) 310
trichlorphon 50
Weedicide (sodium and potassium arsenite) 15, 16, 84, 94, 105, 211, 215, 253, 306, 310
insecticides
Agrocide 81, 113
arsenical dust 293, 294
BHC (benzene hexachloride) 80, 100, 110, 113, 213, 293, 294
Coumarone 62, 196
DDT 293, 294
Dieldrex 232
Dipterex (trichlorphon) 50, 307
endrin 62, 80, 81, 100, 110, 113, 168, 170, 196
fenitrothion 113
Folidol (parathion) 113
Fosferno 119
Furadan (carbofuran) 50
hexachloro-dimethanonophthalene (endrin) 110
Imidan 87
iodine 105

Lannate (methomyl) 50, 87, 159, 182, 263, 270, 307
malathion 110, 113
nicotine sulphate 294
Palmarol 62
parathion 196, 293, 294
Primicid (pirimiphos ethyl) 50
Rhodiatox 118, 293
Rogor (dimethoate) 110
Sevin (carbaryl) 50, 82, 84, 85, 87, 88, 113, 306
Thiodan 113
nematicides
aldicarb 87, 182, 306
aldrin 119
Aramite 119
Basudin (diazinon) 87, 306
Bidrin (dicrotophos) 182
Birlane (chlorfenvinphos) 87
carbaryl 50, 84
carbofuran 50
chlordane 312
chlorocide 119
chloropicrin 32
Cocosev (carbaryl) 84, 306
D-1410 306
D-D 15, 16, 33, 44, 114, 196, 294
diazinon 105, 306
dieldrin 196
diethyl-P-nitrophenol thiophosphate (Rhodiatox) 118
Dipterex (trichlorphon) 50, 307
EN 18133 (thionazin) 15, 16, 105
EPN 18133 95
Ferradow 119
formalin 312
Furadan (carbofuran) 50
methyl bromide 32, 305
Mocap (prophos) 87
Neantina 119
Nemacur (phenamiphos) 87, 181, 182, 306
Nemafos (thionazin) 17, 20, 78, 87, 101, 102, 104, 110, 113, 114, 136, 137, 196, 214
Nemagon (dibromochloropropane) 44, 114
organophosphates 105, 110
parathion 196, 293, 294
Phosdrin (mevinphos) 91, 95, 105, 110
SD 1836 105
SD 4965 (1,6-hexanedithiol diacetate) 105
Semesan 119
Sevin (carbaryl) 50, 82, 84, 85, 87, 88, 113, 306
Solabar (barium polysulphide) 119
Sumithion 87
Temik=*see* aldicarb
Thimet (phorate) 87, 113, 114
thionazin 17
Trithion 110
urea 119
Vapam (metam-sodium) 95, 105
Zinophos (thionazin) 62, 87
of palm weevil
biological 160, 307
fumigation 32
insecticide 293, 294, 305, 311, 312
insecticide, leaf axil application of 80, 81, 84, 87, 88, 110, 159
insecticide, spray 170, 232, 270
palm surgery 50
poisoning palms 180, 211, 306
trapping 50, 51, 59, 208, 213, 263, 270, 274, 305, 306, 307, 318
of R.R.D. 2, 21, 23, 24, 28, 38, 83, 85, 115, 140, 247, 264, 283
banding, with tar and tallow 3, 4
biological 119
burial 13, 59
burning 6, 31, 33, 34, 35, 44, 62, 84, 119, 121, 211, 215, 216, 218, 229, 232, 246, 254, 279, 310, 312
chemical application to the crown 4
chemical application to soil 4, 279, 293
chemotherapy 133, 196
control of humidity 312
control of palm weevil 13, 35, 51, 80, 81, 87, 170, 215, 241, 263, 305, 306, 307
control of vectors (other than palm weevil) 6, 31, 33, 44, 59, 189
cultivation 44, 185, 254, 315
ditching (trenching) 13, 30, 119, 279
drainage 44, 175, 185
fallowing 175, 185, 279
fertilizer application 30, 89
fumigation of cut stems 32, 305
heat sterilization of soil 147
natural dessication 195
nematicide (see also **Nematicides**) 69, 250
injection into roots 62, 78, 114, 196
injection into stem 15, 16, 44, 93, 114, 118, 119, 133, 134, 182, 310
treatment in leaf axils 16, 17, 25, 62, 84, 87, 88, 182
treatment of roots 114
treatment of soil 13, 15, 16, 33, 35, 44, 62, 66, 69, 87, 101, 102, 104, 114, 119, 121, 182, 189, 196, 214, 232, 274, 306, 312
phytosanitation 13, 44, 59, 84, 119, 141, 189, 216, 229, 232, 253, 305, 312
poisoning palms 94, 211, 215, 218, 253, 263, 305, 306, 310
prophylaxis 110, 244
removal of infected material 3, 31, 35, 59, 175, 185, 189, 263, 306, 309, 315
resistance breeding 119, 250, 254, 305, 317
salt 3, 4, 5
sealing cracks in stems 20, 25
therapeutic 110
Coronie wilt 282
Cover crop 10, 279
Crop loss assessment
of coconut palm 58, 92, 110, 160, 244, 264, 267, 268, 269, 270, 306
seasonal fluctuation of 62

***Diplodia* sp.** 42, 120

Dispersal
of R.R.D. 23, 83, 85, 264
by agricultural implements 33, 70, 119, 232
ants 6, 59, 62, 232, 312
chippings, of infected tissue 84, 157, 216, 217, 246
coconut seedlings 33, 109
Coptotermes niger 62, 150, 271
Dinamis politus 44
Eutermes sp. 271
Hemiphileurus sp. 169, 171
Hololepta sp. 169, 171
Homalinotus coriaceus 33, 44, 115, 119
hurricane 160
insects 3, 30, 33, 59, 157, 171
irrigation water 59, 232
Leucotermes tenius 271
lizards 30
man 33, 70
Metamasius hemipterus 169, 171
Nasutitermes ephratae 150, 271
nuts 3, 5, 15, 16, 33, 64, 65, 66, 109, 312
palm weevil 3, 6, 13, 15, 16, 21, 31, 32, 33, 34, 35, 39, 44, 50, 59, 62, 64, 65, 72, 74, 80, 81, 92, 99, 100, 105, 106, 107, 110, 117, 119, 122, 142, 150, 154, 155, 156, 159, 162, 167, 169, 171, 173, 195, 196, 197, 203, 205, 210, 212, 227, 228, 229, 232, 233, 239, 260, 263, 264, 269, 270, 272, 293, 294, 305, 306, 307, 311, 312, 319, 320, 321
palm weevil, non-vectors 162, 163
Parisoschenus obesulus 119
rainwater 3, 156, 312
Rhinostomus barbirostris 33, 44, 50, 119, 169, 171, 307, 312
not-transmitting 233
Rhynchophorus palmarum (see palm weevil)
roots, left in soil 92
root to root transmission 85, 90, 99, 219
soil 13, 15, 16, 33, 62, 64, 65, 66, 69, 79, 87, 99, 119, 156, 157, 321
not transmitted 6, 157
spiders 30
Strategus aloeus 232
tarantulas 30
termites 117, 232, 271
vulture (*Coragyps atratus foetens*) 30
wind-borne 3, 30

Distribution of palm weevil
Geographical
Belize 13
Brazil 33, 44, 119, 293, 294
Caribbean 39, 50, 228, 311
Central America 31, 320
Colombia 31, 122, 260, 311
Ecuador 59
El Salvador 50, 51, 307
Grenada 153, 154, 241, 269
Mexico 142, 233
Panama 39
Peru 197
South America 31, 228
Surinam 195, 202, 203, 204, 205, 272
Trinidad and Tobago 32, 64, 65, 72, 74, 79, 80, 81, 84, 87, 92, 95, 99, 100, 105, 106, 107, 110, 114, 155, 160, 162, 170, 177, 180, 208, 210, 211, 212, 213, 215, 229, 235, 236, 305, 306, 311, 318, 319
Venezuela 6, 227, 232, 263, 264
West Indies 320

Distribution of R.R.D.
Geographical 35, 150, 189
Africa
negative report 121
America, tropical 291, 292
American continent 59
Asia southeast
negative report 63
Belgian Congo
erroneous report 37, 62
Belize 11, 12, 13, 28, 30, 58, 294
Brazil 26, 27, 28, 33, 54, 55, 115, 118, 119, 141, 189, 206, 224, 225, 237, 251, 293, 294, 321
Alagoas 223
Bahia 44, 56
Ceará 252
Paraiba 207
Pernambuco 287
Rio de Janeiro 200
São Paulo 140, 199
British Guiana (see Guyana)
British Honduras (see Belize)
Caribbean 28, 37, 39, 42, 50, 117, 228, 311
Caribbean, northern
negative report 29
Central America 5, 31, 47, 117, 250, 311, 320
Colombia 7, 9, 28, 31, 122, 187, 188, 249, 256, 257, 258, 259, 260, 261, 309, 310, 311
Costa Rica 294
Cuba
erroneous report 115, 192
negative report 52, 53
Ecuador 28, 59
El Salvador 28, 45, 50, 51, 307
Fiji Islands
erroneous report 115, 150
Grenada 4, 28, 30, 38, 152, 153, 154, 241, 242, 269
Guyana 28, 30, 165, 175, 178, 194, 267, 268, 315
erroneous report 164, 183
negative report 34
Honduras 28
India
erroneous report 197, 289, 321
Latin America 28
Malaya
erroneous report 265, 266
negative report 290
Mexico 1, 28, 226
Colima 233
Guerrero 233
Oaxaca 233
Tabasco 142, 233
Veracruz 233

Neotropics 50, 317
Oceania
erroneous report 117, 119
Pacific Islands
negative report 63
Panama 28, 30, 47, 123, 192, 271, 294, 295
Peru 197, 198
Saint Vincent 28, 60, 186, 255
South America 31, 121, 228, 250
Surinam 28, 178, 195, 204, 205, 272, 280, 281, 282, 283, 315
negative report 204
Togo
negative report 201
Trinidad (see also Trinidad and Tobago) 10, 25, 29, 66, 84, 92, 143, 145, 150, 162, 176, 177, 242, 274, 276, 277, 294, 311
Trinidad and Tobago 28, 30, 64, 65, 160, 241, 297, 298, 299, 321
U.S.A.
Florida
negative report 62, 316
Venezuela 28, 30, 48, 57, 221, 227, 232, 250, 262, 263, 264, 294, 296, 308, 315, 322
Windward Islands 60
Local
soil conditions 29, 30, 92, 99, 244, 254, 279
in Palm (see also **Movement** of; **Penetration** of) 24, 66, 73, 75, 242, 321
crown 3, 15, 16, 21, 33
intercellular 15, 25, 132
intracellular 15, 25
leaves 3, 15, 16, 33, 62, 65, 203, 244
ectoparasitic on 178
nuts 3, 5, 15, 16, 33, 39, 64, 65, 66, 109
roots 3, 13, 15, 16, 33, 38, 39, 62, 64, 65, 69, 77, 78, 79, 80, 85, 90, 92, 110, 138, 209, 214, 219, 222, 244, 291, 306
seedlings 3, 109
stem tissue 15, 16, 17, 20, 21, 25, 33, 39, 50, 64, 65, 69, 90, 121, 125, 131, 138, 244, 291
in Palm weevils 106, 142, 196, 204, 253, 269, 270
adult 155, 212
external 39, 72, 106, 110, 156, 157, 167, 168, 170, 173, 227, 229, 233, 236
internal 72, 107, 110, 155, 156, 157, 162, 167, 168, 170, 173, 227, 236, 293
absence of 39
in cocoon 155, 212
in excrement 173, 196, 293, 294
in juveniles 155, 157, 168, 235, 293, 294
during moulting 155
on pupae 79, 155, 236
in Soil (see also **Movement** of; **Penetration** of) 15, 16, 33, 62, 64, 66, 69, 86, 127, 267
clay 86, 217, 218
by depth 86
poorly drained 64, 65, 86
sandy 86, 217, 218
seasonal fluctuations 62

Dye
distribution of in coconut palm 128, 133, 134
movement
in leaves 128, 134
in roots 134
in stem 128, 134

Epidemiology of R.R.D. 160

Fan palm 271
Fertilizer trials 79, 89, 103, 283
Forecasting R.R.D. outbreaks 162
Fumigation (see **Control**)
Fungal infection
of coconut palm 10, 119, 120, 176, 185, 207, 238, 241, 254, 258, 274
Fungicides 50, 279

Geographical distribution (see **Distribution**)
Geotropism
of R.R.D. nematode 39, 82, 108

Herbicides (see **Control**)
History
of R.R.D. 2, 61, 119, 139, 150, 160, 176, 189, 241, 242, 247, 254, 274, 291
Host-parasite relations
of R.R.D. nematodes 28, 66
Host plants, of R.R.D. nematode (see **Alternative hosts** of)
Hosts specificity
of R.R.D. nematode 148
Huntaphelenchoides 239

Immunity to R.R.D. (see **Resistance** to)
***In vitro* tests**
of pesticides 110, 182
Infestation, initial site of 6, 13, 15, 16, 21, 24, 50, 62, 64, 65, 66, 73, 75, 79, 92, 99, 110, 147, 229, 245, 267, 293, 294, 306, 315
Inoculation, with R.R.D. nematodes
of coconut palms 17, 203, 204, 221, 244, 271
crown 4, 6, 135, 138, 157, 245, 291
using infected leaves 195
leaves 15, 16
nuts 3, 16, 19, 109, 111, 112, 157
petioles 131, 245
roots 6, 15, 16, 25, 136, 137, 157, 222
seedlings 3, 109, 111, 112
soil 4
stem 15, 16, 25, 119, 131, 135, 157, 245
of palm weevil 155, 162
of oil palm 48, 178, 202, 203, 204, 221
of wild palms 203, 204, 280
Insect pests
of coconut palm 207
Insecticides (see **Control**)

Kaincope disease 201

Latency
of R.R.D. nematode 109
LD-50
of nematicides 82
Leaf disease 274, 279

Legal aspects
of R.R.D. 58, 153
Lethal yellowing 29, 177, 228, 230, 317
Licula spinosa 130
Life cycle
of palm weevil (see **Palm weevil**)
of R.R.D. nematode 19, 20, 24
Little Leaf Disease 10, 62, 178, 195, 202, 203, 205, 272, 315
Locust 274

***Meloidogyne* spp.** 322
Micrococcus agilis 160
Morphology
of R.R.D. nematode (see **Taxonomy**)
of palm 113
Moth Borer (see ***Castnia daedalus***)
Movement (see also **Distribution, Penetration**)
of R.R.D. nematode 217
effect of
CO_2 21, 22
relative humidity 3
temperature 108
in leaves 3
into roots 13, 77, 78, 219, 222
from root to stem 13, 39, 110, 209
absence of 209
in soil 127
in stem 3, 21, 131
outside stem 291
from stem to root 3
on surfaces 2, 108
in tissue 15
in water 2, 108

Nematicides (see **Control**)
Nematodes
associated with coconut palms 52, 53, 127, 201, 231, 238, 316, 322
Nutrition studies (see **Fertilizer Trials**)

Origin
coconut palm 189
R.R.D. 228
Oryctes rhinoceros 270
Oxygen 24

Palm weevil (see also **Dispersal of R.R.D.**)
breeding, for food 204
defence mechanism 163
genetics 162
infestation with R.R.D. (see **Distribution**, in palm weevils)
life cycle 50, 79, 172, 307, 319, 320
populations 80, 142
seasonal fluctuation 106, 168, 170, 208
size structure 162
pupation, in soil 79, 212
size 50, 157, 162, 269
transmitter of *Rhabditis* 156
Paraphelenchus 234
Parasitaphelenchinae 28
Parasitaphelenchus 239
Pathology, of R.R.D. 85
Pencil Point Disease 267
Penetration
of R.R.D. nematode into
crown (including leaf axils) 6, 15, 50, 62, 73
petioles 15, 73
roots 13, 15, 62, 66, 73, 78, 79, 92, 99, 110
stem 15, 21, 25, 73
stomata 62, 147
prevention of 82
wounds 147
Persistence
of insecticides 113
of nematicides 104, 181, 182
of R.R.D. nematode in roots 92
***Pestalotiopsis* sp.** 10
Phototropism
nematode 39, 108
palm weevil 312
Phytophthora palmivora 230, 270
Phytotoxicity
nematicides 17
Phytotoxin 96, 125, 130, 196
Polynesia 189
Population
of R.R.D. nematodes
in coconut palm 35, 41, 90, 196, 249
in oil palm 249
in/on palm weevils 106, 107
seasonal fluctuation
on coconut palm 170
on palm weevil 202
Pratylenchus penetrans 313
Ptychorapis augusta 130

Quarantine 5, 62

Red ring
caused by *Thielaviopsis* 197
development 50, 274
diffuse 50, 185
histopathology 21, 132
location 50, 65, 132, 177, 185, 279
nature 21, 130, 229
produced in nuts 3, 5, 15
Repellants 50
Reservoir of R.R.D. 160
Resistance
of coconut palm
to Lethal yellowing 317
to R.R.D. nematode (see also **Susceptibility, Tolerance**) 6, 23, 77, 249, 254, 267, 270, 274, 279
breeding for (see **Control** of R.R.D.)
following chemical treatment 78, 136, 137
of roots 114, 214
in nuts 20
in young palms 3, 221
of native palms
to R.R.D. nematodes 119
of oil palm
to R.R.D. nematodes 249, 250
of R.R.D. nematode

to control 31
to dessication 2
Rhabditis 156
Rhadinaphelenchinae 184
Rhadinaphelenchus 143, 144
Rhadinaphelenchus cocophilus
development 50, 156, 160
effect of CO_2 20, 21, 22, 24
effect of O_2 24
Rhina = *Rhinostomus*
Rhinostomus barbirostris (see also **Dispersal**) 294
Rhynchophorus palmarum (see **Dispersal,** palm weevil)
Roots
aerial 129
wilt disease 230

Saint Paul Wilt (see **Kaincope Disease**)
Salt 3, 4
Scale insect 274
Seinurinae 184
Site of initial infestation (see **Penetration, Distribution,** of R.R.D.)
Soil (see **Control, Dispersal, Distribution**)
Strategus **sp.** 270
control 232
Strategus aloeus 267
Survival
of R.R.D. nematode 108
effect of
light 124
soil moisture 85, 86, 195
soil type 86
temperature 108
in crown 138
desiccation 2
in glucose solution 124
in nuts 5, 111, 112
in palm weevil
excrement 167, 173, 174
externally 168
internally 167, 168, 170
in roots 138
in salt solution 2, 39
in sea water 2
in seedlings 111, 112
in sodium bicarbonate 2
in soil 15, 16, 17, 69, 86, 127
in stem 138
in sucrose solution 124
in water 2, 108, 124
Susceptibility (see also **Resistance**)
to R.R.D.
coconut palm 3, 5, 6, 15, 20, 24, 25, 30, 39, 65, 77, 78, 103, 230, 233, 249, 315
oil palm 48, 249
Symptoms
of R.R.D.
in coconut palm 6, 33, 35, 37, 44, 65, 119, 139, 140, 229, 242, 245, 247, 260, 264, 274, 293, 312, 321
external 5, 15, 16, 17, 30, 90, 125, 126, 130, 131, 135, 175, 178, 185, 195, 196, 203, 220, 222, 228, 241, 291, 294, 298, 315
internal 15, 25, 30, 90, 131, 138, 175, 185, 196, 203, 241, 254, 291, 294, 298
little leaf 10, 62, 178, 195, 202, 203, 205, 272, 315
nut infection 3, 5, 15
in roots 90, 117, 175, 185, 196, 214, 241, 254
seedlings 112
varietal differences 50
in oil palm 62, 178, 195, 202, 203, 204, 221, 250, 260

Taxes (see **Tropisms**)
Taxonomy
of R.R.D. 28, 38, 40, 42, 115, 117, 119, 139, 144, 145, 148, 150, 151, 156, 184, 200, 220, 234, 239, 273, 284, 285, 286, 291, 312
history 143, 284, 285
Techniques
Culturing R.R.D. nematode
on immature nuts 19
in vitro 124
Embedding of coconut tissue 132
Extraction of nematodes from palm weevil 106
Fixing
of coconut tissue 132
of R.R.D. nematode 147
Injection into coconut palm
of dyes 128, 134
gravity technique 93, 94, 95, 96, 128, 133, 211
Leaf perfusion tests 91
Quantitative recovery
of nematodes 97
Screening
insecticides 79, 87, 113
nematicides 82, 84, 87, 91, 105, 108, 113
for R.R.D. resistance 187, 188
Stickers
used with pesticides 113
Weathering tests
on pesticides 113
Thielaviopsis paradoxa 197
Thrinax morissii 130
Tolerance
of coconut palms
to R.R.D. infestation 51, 279
Tomato
wilt 130
Toxic secretions 33, 230
Toxicity
of pesticides 113
Tropisms (see **Chemo-, Geo-** and **Phototropism**)
Turbatrix aceti 82, 105, 110, 181, 182
Tyloses 16, 17, 25, 313

Unknown disease (see also **Lethal Yellowing**) 228, 230

Variety trials 187, 188
Vascular tissue
blockage 96, 125, 132, 179, 313
xylem 15, 16, 17, 20, 22, 25
Vectors (see **Dispersal of R.R.D.**)
Vivotoxin (see also **Phytotoxin**) 125

Water uptake
of coconut palms 93, 96
Weed control 283
Weedicide (see **Control**)

Xanthopygus cognatus 307